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An Analysis of a Methodology for Generating Watershed Parameters using GIS

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Abstract

An Analysis of a Methodology for Generating Watershed Parameters Using GIS

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A basic methodology is presented for generating watershed parameters in a GIS format. The calculation of drainage area, average curve number, and average precipitation parameters were made for water right locations as part of the TNRCC's Water Availability Modeling project for the Nueces, Guadalupe, San Antonio, and San Jacinto river basins. The effectiveness of the methodology was analyzed. The study showed that 90-meter (1:250,000 scale) DEMs alone could not be used to accurately delineate watersheds. However, 30-meter (1:24,000 scale) DEMs were used to accurately delineate watersheds ranging from a size of 10,000 square miles to 0.15 square miles in areas with well-defined drainage. The limitations of using 30-meter DEMs were a 10-fold increase in both file size and processing time. Also, the increased resolution of the DEMs still had difficulty defining accurate watersheds in areas with an average slope of less than 0.002 m/m.

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CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

The vast area covered by the State of Texas can become a problem when studying water resource issues. For example, the eastern portions of Texas receive an abundant amount of rain, while the western portions are virtually dry. Even during normal rainfall periods, some areas lack sufficient water supplies to meet all demands. This lack of water is magnified in periods of drought, to the extent that essential needs may be threatened. These issues alone require extensive planning for current and future water demands. If we also consider the effects of population growth, as well as new and emerging environmental issues, the need for complex management tools to identify, assess, and resolve these water resource issues becomes evident. The State of Texas is a leader in the acquisition, maintenance, and use of planning tools, such as water availability models (TNRCC, 1998).

Water availability models are computer programs that calculate the amount of water in a river basin, using both hydrologic principles and actual measurements taken at stream gages. During the 1970s and 1980s, the predecessor agencies of the Texas Natural Resource Conservation Commission (TNRCC) developed water availability models for 8 of the 23 river basins within the State. These models were basin-specific and are now considered obsolete. These older models lack the design capacity to handle the data inputs and calculations needed for full water resource management in Texas, and their data reside in obsolete mainframe computer systems (TNRCC, 1998).

When a severe drought hit the Texas area in the summer of 1996, water resource management issues were brought to the forefront. By August, many lakes were far below their normal levels, while streamflows in rivers and creeks ranged from 11 to 50 percent of average historic flows. Disputes arose over water use as a result of uncertainty about the reliability of Texas' existing water supplies and the ability to develop new supplies (TNRCC, 1998).

In January of 1997, the Texas Legislature responded by drafting Senate Bill 1. This legislation addressed a wide range of water management issues, including the provision of funds to the TNRCC to begin development of water availability models for 22 of the state's 23 river basins. The new models form a complete modeling system for the state: The Texas Water Availability Modeling System (WAM). The components of the WAM system include a database of water rights, water uses, streamflows, and other data; Geographic Information System (GIS) tools to analyze drainage basin characteristics; and the water availability model (TNRCC, 1998).

Much of the cost and time-consuming work in developing a water availability modeling system lies in the calculation of the input data. This process includes estimating "naturalized" streamflows and accounting for water demands. "Naturalized" streamflows refers to the water that would historically flow in a river without human impact, while water rights refer to locations where legal permits exist to draw water from rivers and streams. Once "naturalized" streamflows are calculated, all permitted water withdrawals for existing water rights are subtracted in priority order to determine how much water remains for permitting and other purposes (TNRCC, 1998). The priority system is established on a seniority basis, which means a senior water right is entitled to its allotment of water before any water right junior to it.

In part, this thesis presents an approach for calculating the input data required for the Texas Water Availability Model. The input data includes the drainage area, average curve number, average precipitation and next downstream point for each water right in the study area. With 22 river basins and over 8000 water rights in the state, hand calculations are not at all feasible. However, GIS offers an ideal environment for this type of work. GIS allows for the manipulation of large amounts of data and provides a format to study the data in large-scale situations, such as the entire state of Texas.

A basic methodology for calculating the input data had already been established by a previous researcher on the WAM project, Brad Hudgens (1999). Therefore, in addition to presenting the methodology, this thesis also includes case studies of 4 basins completed over the last year: Nueces, Guadalupe, San Antonio, and San Jacinto. The purpose of these case studies is to analyze the effects of changes in the methodology on the accuracy of the output watershed parameters.

1.2 OBJECTIVES

There were four primary objectives of this research:

1. Acquire and generate GIS data layers for all 4 basins in the study area. These layers include basin boundaries, river networks, digital elevation models (DEMs), digital raster graphic maps (DRGs), water right locations, stream gage locations, Soil Conservation Service (SCS) curve number grids and mean annual precipitation grids.
2. Use ArcView GIS and Arc/Info GIS utilities to develop a spatial water rights database for each basin. These databases include watershed parameters for each water right and stream gage location, called "control point locations." The following are the watershed parameters needed for each control point: (1) delineated upstream drainage area, (2) average SCS curve number for that drainage area, (3) mean annual precipitation for that drainage area, (4) downstream flowlength along the river to the basin outlet, and (5) next downstream control point.
3. Analyze the results of each basin on a case-by-case basis. Changes in the methodology were made throughout the process as new data became available and problems where encountered. The case studies focus on the effects that these changes had on the final results.

4. Synthesize the results from each case study in order to assess the accuracy of the results with respect to data resolution (90m vs 30m digital elevation models) and degree of terrain relief (slope).

1.3 STUDY AREA

As per Senate Bill 1, water availability models were developed for six of states major river basins in Texas by December 31, 1999. Brad Hudgens (1999) developed the parameters for the first 2 basins in the study (Sulphur and Neches), while this research focused on the final 4 basins: Nueces, Guadalupe, San Antonio, and San Jacinto. Figure 1.1 is an image showing the location of the basins studied in this research.

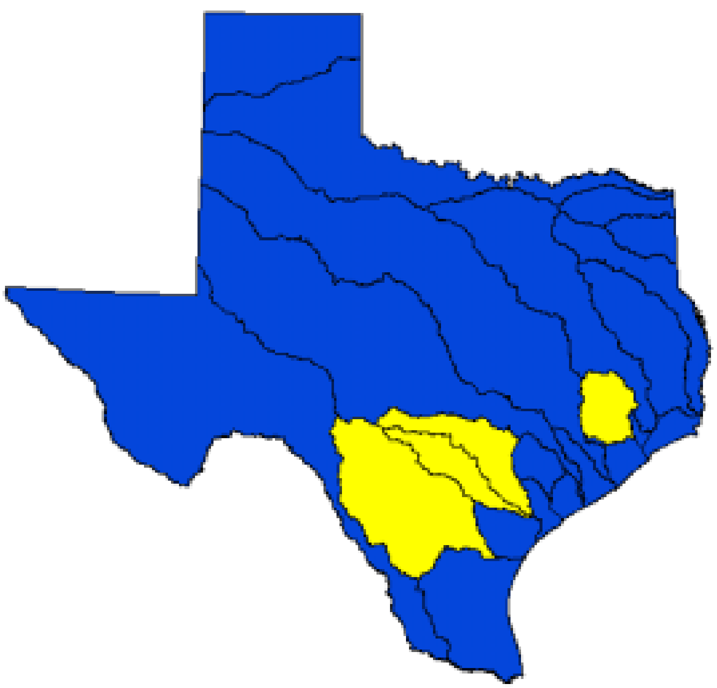

Figure 1.1: Image of Texas river basins. Highlighted, from left to right, are the Nueces, San Antonio, Guadalupe, and San Jacinto

1.4 METHODS

Achieving these objectives required research into what data sets are available and which ones best suit the needs of the project. The main sources of data acquisition were the United States Geological Survey (USGS), the Environmental Protection Agency (EPA), and TNRCC, all of which provide very current GIS data files that are essential for accurate results. Most of the files were obtained by downloading them from the websites of the above agencies.

Once all the files for a basin were downloaded, the next step was to edit the data in ArcView and Arc/Info. For example, the river networks obtained from the EPA contained many unwanted features, such as lakes and braided streams. For the purposes of this project, only a single-line stream network (i.e. a single path for every stream from top to bottom) was needed. Therefore, these unwanted features had to be located and deleted before continuing with the processing. Once the streams were edited, the water rights were located along the stream network.

Another essential piece of the processing was the use of the Center for Water Resources Pre-Processing tools (CRWR Pre-pro). As an extension of ArcView, these tools served to create data layers from the original DEM. The single-line stream network was combined with the DEM to create a flow accumulation grid. Using this grid, along with the water rights that had previously been located, the value of the drainage area was found for each water right location. A similar process was used to find the average SCS curve number and the mean annual precipitation for these points.

The final parameters in the database were found through the use of tools developed at CRWR. For example, a script was written that snapped the water right points to the stream network. Once the points were snapped, the script was then able to follow the single-line network downstream until it located the next point. The downstream flowlength was found in a similar manner (i.e. tracing a path downstream).

1.5 OUTLINE

The research detailed in this thesis not only shows an approach for calculating watershed parameters for a number of locations, but also provides an analysis of the accuracy of the results for each of the four basins studied. This thesis is divided into nine chapters. Following the introduction, a comprehensive literature review was performed, which resides in Chapter 2. The third chapter contains background information on GIS and GIS tools, as well as information on the data files that were used in the research. Chapter 4 provides a brief explanation of the methods used to calculate the required parameters from the acquired data sets. A more detailed description of these methods can be found in Brad Hudgens (1999). Chapters 5, 6, and 7 contain the case studies of the four basins studies (Nueces in Ch. 5, Guadalupe/San Antonio in Ch. 6, and San Jacinto in Ch. 7). Chapter 8 presents a synthesis of the case study results, with a discussion of the effects of each methodology change. The final chapter presents the conclusions and recommendations for further research in this area. The Appendix contains additional information on the results of this research.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

Before this research was undertaken, an extensive literature review was performed to establish the state of knowledge in the area of terrain analysis. Because most of the advances in this area occurred in the last 15 years, ample literature exists.

2.2 TERRAIN ANALYSIS

Original terrain analysis studies simply consisted of the visual interpretation of maps and aerial photographs. However, manual interpretation of such products and the subsequent measurement or digitization of topologic properties was quite tedious for any but the smallest data sets (Band, 1986). With over 8000 water rights to be concerned with in Texas, automated methods using geospatial data had to be utilized. The growing availability of digital elevation models, produced by the USGS, facilitated the applicability of automated techniques to a variety of hydrologic research (Band, 1986).

In the mid 1980's, several methods were developed to extract hydrologic information automatically from DEMs. Before using the DEM, however, it was recommended that the data be processed through a 3-step conditioning phase. As Jenson (1991) showed, depressions in the DEM were first "filled" by raising the values of cells in depressions to the value of the depression's spill point. Next, the computation of the flow direction for each cell in the depressionless DEM was performed. The direction water will flow out of each cell is encoded to correspond to the orientation of one of the eight cells that surround the cell. In flat areas, the flow directions are iteratively calculated so that the flow path traverses the flat area and continues downhill to one of the flat area's spill points. This process of defining flow direction performs well on land surfaces characterized by well-established drainage patterns. The third conditioning step is the computation of the flow accumulation value for each cell. This is the count for each cell of how many upstream cells would contribute drainage to it based on their flow directions. After the conditioning phase, the datasets can be further processed to delineate watersheds.

Although Jenson states this process to be accurate in well-defined areas, problems can arise in areas of low relief. Research by Saunders (1996) confirmed the accuracy of the method in the topologically diverse portion of the San Antonio-Nueces river basin away from the coast, showing close agreement with the generally accepted USGS 1:100,000 scale stream network and USGS Hydrologic Cataloging Units. However, in the near-coast portions of the basin, where slopes were generally flat, drainage paths were distorted and tended to "short-circuit" the actual known locations of streams. Jenson's method interprets watersheds from the digital terrain information. But, depending on the DEM resolution, valuable stream information can be missed when defined by a DEM alone.

Kirkby (1993) explains the importance of the digital stream network. Since the channel network is the focus for the interacting processes that carry water out of the drainage basin, it is ultimately responsible for shaping the landscape. Thus, the network is the framework to tie together and structure the distribution of all watershed information required for simulation of a broader range of hydrological processes.

Maidment (1996) suggests a variation to the DEM processing method. Since critical errors can occur when only using the DEM to define the drainage network, it is suggested that the DEM grid be used in conjunction with a mapped representation of the stream network, such as the EPA's River Reach file. The mapped streams can be converted into a grid and "burned in" to the DEM by artificially raising the elevation of the off-stream cells. This technique requires editing the stream network to eliminate any artifacts that would confuse the delineation process, such as loops and gaps. Although some distortion of watershed boundaries still occur, the burning in method has the great advantage of the DEM delineated streams matching the mapped streams exactly. Again, it follows the theory that it is the stream network that is really the critical item in landscape delineation. The "burn in" process technique is especially useful in coastal zones with very flat terrain and other locations where drainage is directed through constructed channels.

Other issues arise when combining vector data layers with raster DEM layers. Not all vector and raster data layers have sufficiently compatible map scales for the integration process. For example, Saunders (1999) points out that a vector data layer should never be burned into a raster data layer of coarser resolution. Figure 2.1 shows the problem of burning streams into a DEM when the two layers are not of similar scales.

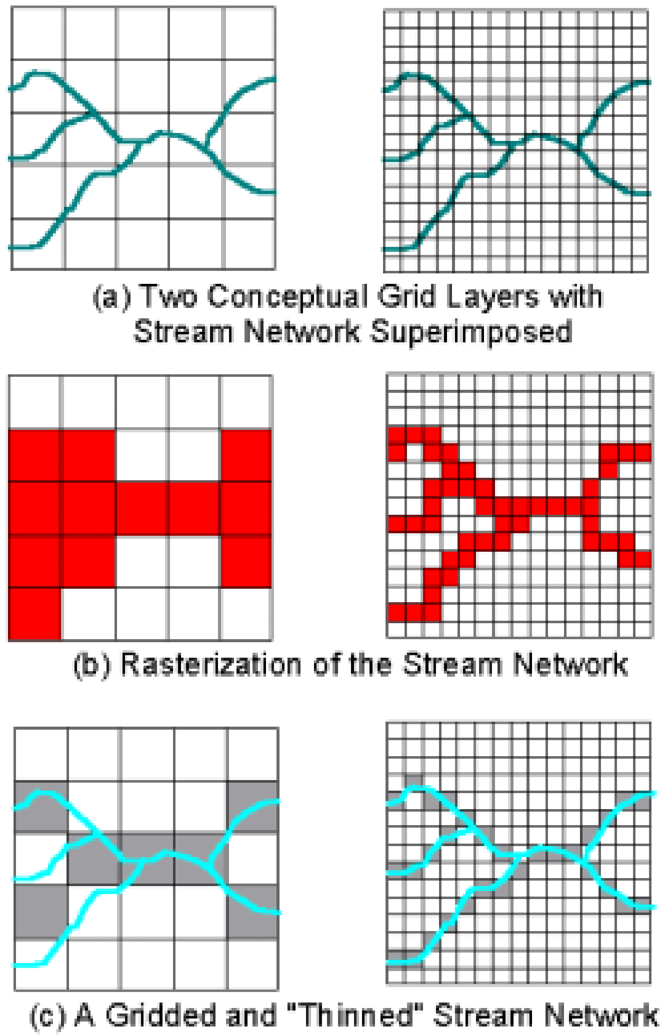

Figure 2.1: Burning streams into grids of different scales (Saunders, 1999)

Figure 2.1a shows a fine scale network superimposed on both a coarse and a fine scaled DEM. The conversion of the vector stream network into a raster network is shown in Figure 2.1b. Note that a grid cell is created where any portion of the vector network is located. Figure 2.1c shows the final, digital stream network, which reduces the flow network to strings of single cells. Also in

Figure 2.1c, the original vector network is superimposed on the raster network to show that integration of the fine scale layer into the coarse scale DEM results in an oversimplification of the stream network (Saunders, 1999).

Maidment (1996) suggests that DEMs of 30m (1:24,000 scale) and 90m (1:250,000 scale) cell size should be used for regional studies the size of Texas. However, at the inception of this project, only 90m data existed for the entire state. Therefore, previous work on areas of this size relied heavily on the use of 1:250,000 scale DEM data. Since nationwide, vector stream data only exists at 1:100,000 scale, the issue of conflicting scale was an issue in the previous work on the Water Availability Modeling project by Hudgens (1999). Short-circuiting of the stream network occurred when vector streams were located closely together. Thus, results were not always accurate. Hudgens (1999) also showed the inability of 1:250,000 scale data to accurately calculate the area of small watersheds. Hudgens (1999) explained the necessity to quality control all watersheds with a flow accumulation of less than 1000 cells.

This research makes use of the relatively recent availability of the National Elevation Dataset, a 1:24,000 scale DEM for the entire State of Texas. At this time, no previous studies can be found evaluating drainage areas produced from 1:24,000 scale data for an area the size of a major river basin.

2.3 Conclusion

Terrain analysis has progressed considerably from the days of manual delineation. Although manual delineation may still be required to define drainage in problematic areas, automated methods have been proven to be both accurate and efficient. Aside from the ample amount of literature on the results of automated delineation processes, this research will contribute an analysis of the results obtained from the incorporation of newly created, 30m data. Comparisons will be made between results from 90m data and 30m data on the same area to evaluate the accuracy and efficiency of the standard methodology. Also, an assessment of the level of quality control needed when using 30m data will be made (i.e. the validity of the 1000 cell flow accumulation threshold for small watersheds).

CHAPTER 3: SYSTEM AND DATA DESCRIPTION

3.1 INTRODUCTION

Because GIS and digital data were valuable tools in the work performed for this thesis, it is appropriate to discuss the features and advantages of GIS, as well as describe the data sets used. This chapter will cover both tasks.

3.2 GEOGRAPHIC INFORMATION SYSTEMS

Before entering into a description of the data used in this research, it is first important to gain an understanding of GIS and the tools used to manipulate the data. Use of GIS has grown dramatically over the past decade, and it is now commonplace for business, governmental, and academic institutions to use GIS for many diverse applications. Consequently, many definitions of GIS have developed (ESRI, 1997). However, perhaps the most concise definition of GIS is that offered by the Association for Geographic Information: "A system for capturing, storing, checking, integrating, manipulating, analyzing and displaying data which are spatially referenced to the earth."

From this definition, we see that GIS is not simply a computer system for making maps, as most people assume. A GIS is an analytical tool. The major advantage of such a tool is that it allows you to identify the spatial relationships among map features (ESRI, 1997). This ability was fundamental in the choice of GIS for the Water Availability Modeling research project. By overlaying maps of water rights, river networks and river basins, relationships between features can be found. For example, we can know which water right fell on which river reach and in which basin, and which water rights are upstream and downstream of the current one. This process has previously been done by manual interpretation of paper maps, often a cumbersome procedure.

Another important feature of GIS is the linking of spatial data with geographic information about a particular feature on a map. Each feature in a GIS map is linked to a set of attributes that is stored in a database (ESRI, 1997). Therefore, a person can query a feature on a map and retrieve a wealth of information about the map feature. The programs used to perform such queries and analyses in this study were ARC/INFO GIS and ArcView GIS, both developed by the Environmental Systems Research Institute (ESRI).

ARC/INFO and ArcView differ in a couple of very distinct ways. For example, ARC/INFO uses a command language that functions similarly to the way a computer's operating system works: commands are entered at a prompt before different tasks (ESRI, 1997). However, ArcView is a much more visual medium for working with maps. Based totally in a Windows operating system, operations and commands are performed mainly through menu options and user-created scripts (or programs), rather than built-in functions.

3.2.1 Raster vs. Vector Data

Date format is another important issue when discussing GIS. Data in GIS can be represented in either a raster or vector format. A raster-based system displays, locates, and stores graphical data by using a grid of cells. Each grid cell is represented by a unique reference coordinate at either the corner or centroid of the cell. In addition, each cell has discrete attribute data assigned to it (Foote, 1996). An example of such data is a Digital Elevation Model.

In contrast, vector based systems display graphical data as points, lines or areas with attributes. Cartesian coordinates (i.e., x and y) and computational algorithms of the coordinates define points in a vector system. For example, lines are represented as a series of points, while areas are stored as a series of points with the beginning and end points at the same node, so that the shape is closed. The graphical output is very similar to hand-drawn maps (Foote, 1996). An example of vector data is the EPA's river reach file. The following figure is a comparison of vector and raster data.

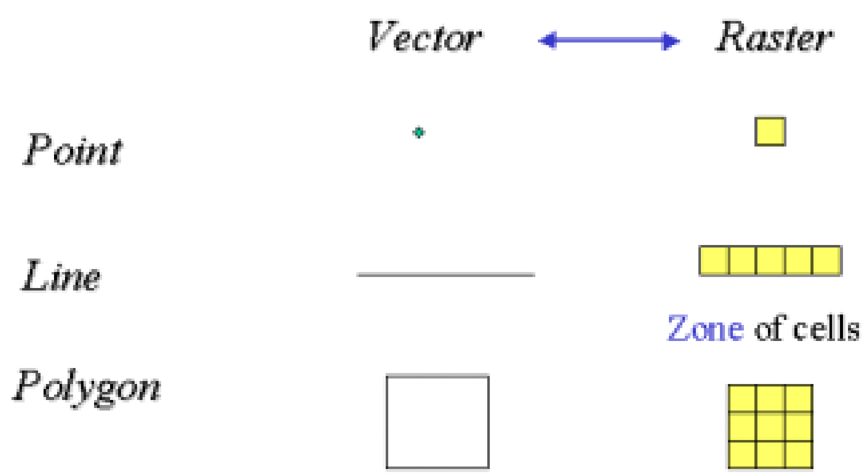

Figure 3.1: Comparison of features in raster and vector format (Maidment, 1998)

Following this brief description of GIS, the next step is to take a look at the data that were used in building the water rights database.

3.3 DATA DESCRIPTION

Many different types of data are required for a project that will eventually provide information on the entire state of Texas. Therefore, it is important to take a look at each data set in detail. The following is a list of the data sets to be discussed in this section:

- Digital Elevation Models
- Environmental Protection Agency River Reach Files (Version 3.0)
- Water Right Locations
- Digital Raster Graphics
- Precipitation Grids
- Curve Number Grids

3.3.1 Digital Elevation Models

One of the most important data sets needed for drainage area calculations is an accurate representation of the land surface. In a GIS framework, a Digital Elevation Model (DEM) contains such information. A DEM consists of a sampled array of elevations for ground positions that are normally at regularly spaced intervals, as shown in Figure 2.2.

67	56	49	46	50
53	44	37	38	48
58	55	22	31	24
61	47	21	16	19
53	34	12	11	12

Figure 3.2: Sample representation of a DEM (Maidment, 1998)

In the early stages of this project, the best available data sets were 90-meter DEMs (3 by 3-arc second spacing), which contained elevation values at approximately 90-meter intervals (USGS, 1996). However, during the course of the work, the National Elevation Dataset (NED) was made available for the state of Texas. The NED files (or 30-meter DEMs) are DEMs with grid cells of 1 by 1-arc-second spacing or elevation values at 30-meter intervals. The next section discusses these two data sets in detail.

3.3.1.1 - 90-meter DEM

The 90m DEM (often called the 3 arc-second DEM) provides coverage in 1- by 1-degree blocks for all the contiguous United States. The majority of the 3 arc-second DEMs were produced by the Defense Mapping Agency (DMA) from cartographic and photographic sources. However, the final product is distributed by the USGS EROS Data Center (USGS, 1996).

Elevation data from cartographic sources are collected from USGS 7.5-minute through 1-degree maps. Topographic features such as contours and ridgelines are first digitized and then processed into the required matrix form and interval spacing (USGS, 1996). Figure 3.3 shows an example of DEM elevation values in comparison to contour lines on a topographic map.

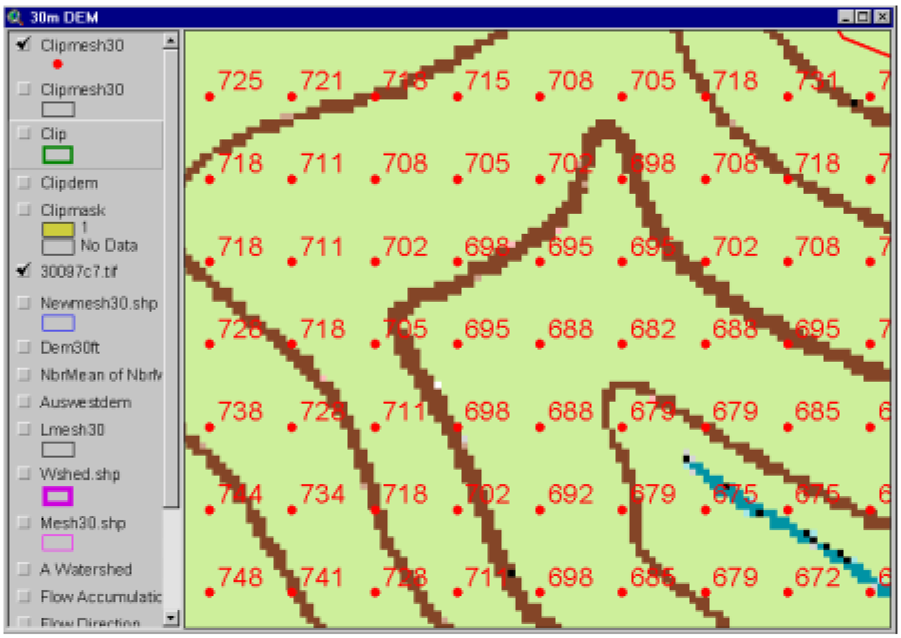

Figure 3.3: Image of DEM elevations overlain on topographic contours (Maidment, 1998)

Manual and automated correlation techniques are used to collect elevation data from photographic sources. First, the elevations along a profile are collected at 80 to 100 percent of the eventual point spacing. Then, the raw elevations are weighted with additional information during the interpolation process in which final elevations are determined for the required matrix form and interval spacing (USGS, 1996).

The elevation data for the 3 arc-second DEM are referenced horizontally on the geographic (latitude/longitude) coordinate system of the World Geodetic System 1972 (WGS 72) and are referenced vertically in meters relative to the National Geodetic Vertical Datum of 1929 (NGVD 29). The data are approximately equivalent to that which can be derived from contour information represented on 1:250,000 scale maps (USGS, 1996).

Each file contains 1201 rows and columns or approximately 1.4 million cells and takes 6.91 MB of memory with elevations in floating point meters. The river basins covered by this study require 4-6 one-degree blocks to cover them. Typical grid sizes for the river basins were 10 million cells.

3.3.1.2 - 30-meter DEM

The NED is a new raster product assembled by the USGS and has a resolution of 1 arc-second (approximately 30 meters) for the conterminous United States. The NED is designed to provide national elevation data in a seamless form with a consistent datum, elevation unit, and projection (USGS, 1999).

Building a seamless elevation database involved a complex system for performing the conversion and transformation of over 50,000 DEM files. Once all the DEMs in the National Digital Cartographic Database were identified, the system accomplished the following: filtered production artifacts, computed datum conversions, appended individual DEM files, computed coordinate transformations, resampled data; merged the various sources, and performed edge matching between each separate DEM file. As with the 90-meter DEM, the files were stored in 1-degree by 1-degree blocks (USGS, 1999). Each file in this dataset contains 3600 rows and columns or approximately 12.9 million cells and takes 52.8 MB of memory with elevations in floating point meters. Typical 30-meter grid sizes for the river basins were 60 million cells.

Unlike the previous 30-meter DEM sources, the final NED product has universal data characteristics. In the NED assembly process, the elevation values were converted to decimal meters as a consistent unit of measure; North American Datum 1983 was consistently used as the horizontal datum; and all the data were recast into a geographic projection, whereas the earlier 30-meter DEMs were in UTM projection (USGS, 1999).

3.3.1.3 - DEM Accuracy

The main factors that determine the accuracy of a DEM are the source resolution and the spatial resolution (or grid spacing) of the data profiles. Since a dependency exists between the scale of the source materials and the level of grid refinement possible, the source resolution determines the level of content that may be extracted during digitization. Within a standard DEM, most terrain features are generalized by being reduced to grid nodes spaced at regular intersections in the horizontal plane. This generalization reduces the ability of the DEM to represent positions of specific features smaller than the internal spacing of the nodes and results in a “smoothing” of the surface during gridding (USGS, 1996). Therefore, the assumption is that higher resolution data (i.e. smaller grid spacing) more accurately represents the drainage features of the terrain and results in more accurate watershed delineations.

3.3.2 River Reach Files

In order to perform any study of this kind, there is a need for some representation of the rivers and streams that dominate the water flow in the area. For its accuracy and breadth of information, the Environmental Protection Agency's River Reach File Version 3, known as RF3, was used as the stream network representation. RF3 is a national hydrologic database that interconnects and uniquely identifies the 3.2 million stream segments that comprise the country's surface water drainage system (Dewald, 1994). These vector data sets contain digital images of many surface water features, including rivers, streams, lakes, reservoirs and canals. Figure 3.4 shows the RF3 file for the San Jacinto River Basin, located on the Gulf Coast of Texas.

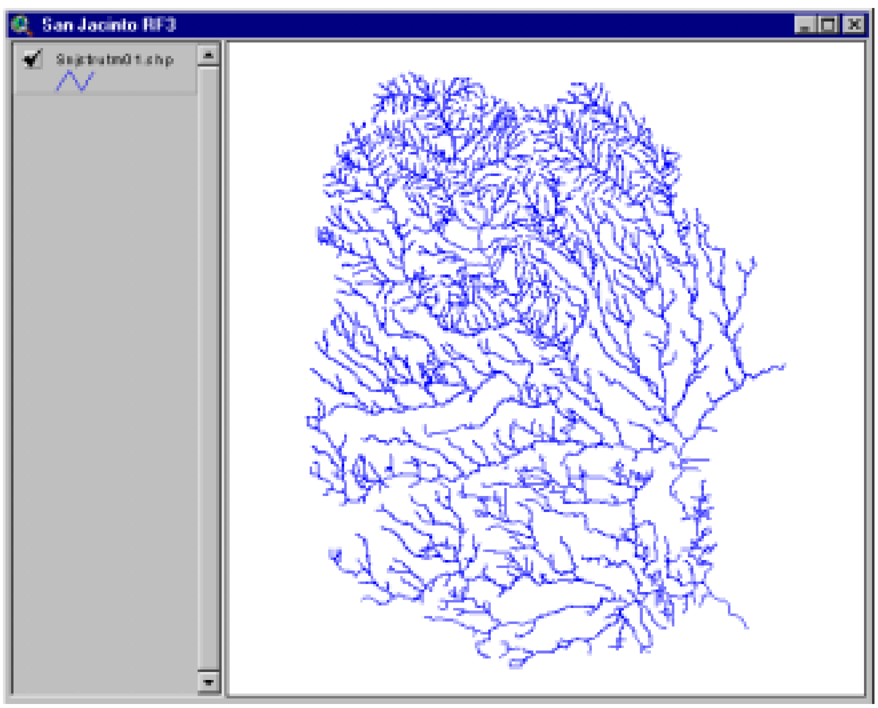

Figure 3.4: River reach file for the San Jacinto basin

The RF3 production process was two-fold: 1) compilation of spatial and attribute data from existing sources; 2) assignment of reach codes to the segments in the network. The compilation part of RF3 production involved the combination of the following: 1) relevant portions of the first two versions of the reach files (RF1 and RF2); 2) the USGS Geographic Names Information system database; 3) the 1988 USGS 1:100,000 scale hydrography dataset. The second part of RF3 production involved the assignment of a unique reach code to each segment contained within the USGS hydrography. The reach codes contained within RF3 uniquely identify, by 8-digit Hydrologic Unit Codes (HUC), the individual components of the Nation's rivers and lakes. The reach code assignment process allowed for the determination of the upstream/downstream relationship of each river reach. Thus, by piecing together all the reaches in the proper order, a national hydrologic network was formed (Dewald, 1994).

During this research, USGS was working on another set of river reach files called the National Hydrography Dataset (NHD). The NHD is the culmination of a cooperative effort between the EPA and the USGS. It combines elements of USGS digital line graph (DLG) hydrography files and the USEPA Reach File (RF3). An important addition to the NHD is the inclusion of flow direction and centerline representations through surface water bodies (USGS, 1999). Although the entire dataset was not available for use in the basins studied in this research, the NHD centerlines were utilized in the stream editing process discussed in Chapter 4.

The value of RF3 to the Water Availability Modeling project was clear. The extensive coverage of the river reach files provided an additional source of information for defining the drainage patterns of the landscape. Also, by using a nationally consistent hydrologic network, permit writers (namely TNRCC) had the ability to “navigate” upstream or downstream when assessing the effect of one water right on another in the network.

3.3.3 Water Right Locations

Along with the quantification of naturalized flows, the second part of the Water Availability Modeling system is the calculation of water that is drawn out of the system by landowners. Since all water in rivers, streams, lakes, etc. belongs to the state, a person must acquire the “right” to withdraw water from the natural system. This, quite simply, defines a water right. Therefore, compiling the locations of all existing water rights became a task in this research.

All permits for water rights must be requested from the TNRCC. Once requested, the TNRCC determines whether water is available, and if so, grants the permit. Once granted, the water right is located on a paper map and given a spatial coordinate (latitude/longitude). From these records, a GIS point coverage was created to represent all the water right locations on a river or stream in the surface water network, as shown in Figure 3.5. The process of creating the point coverage is discussed in Chapter 4.

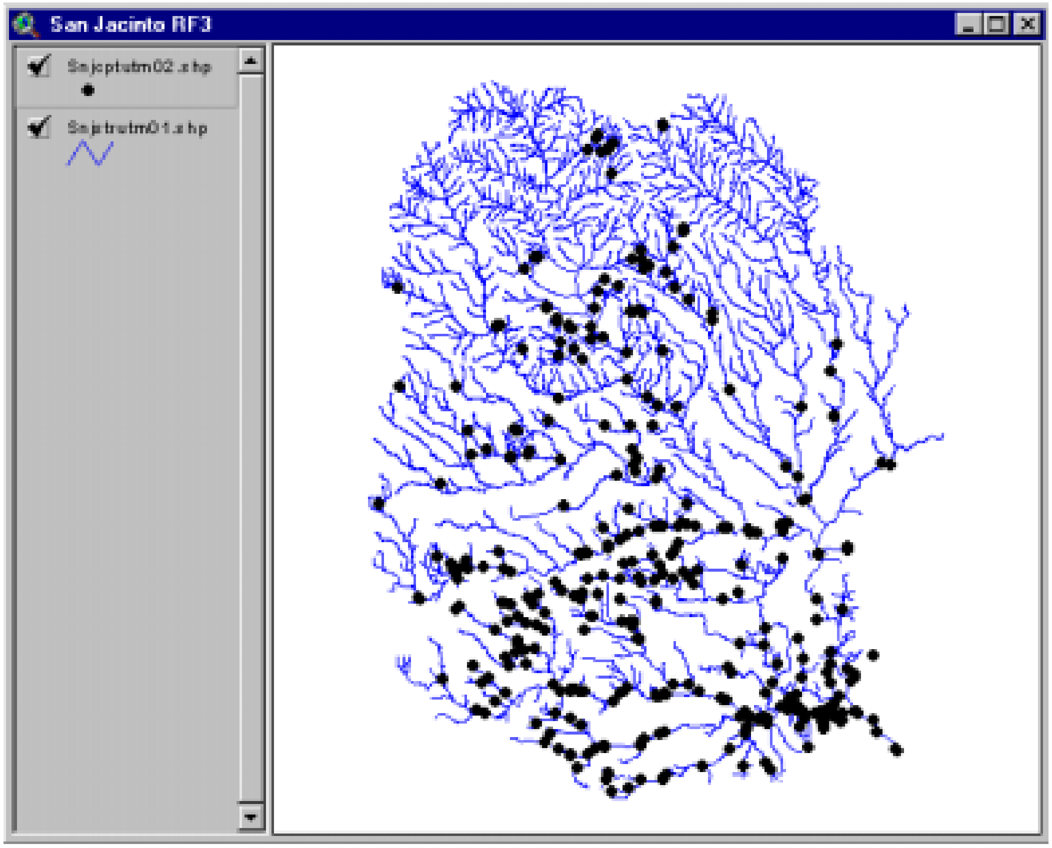

Figure 3.5: San Jacinto water rights overlain on RF3

3.3.4 Digital Raster Graphics

Although the RF3 is considered to be a good representation of the river network, errors in the files do exist. However, without any other information, these errors can go unnoticed. Therefore, a need existed for another source of terrain information to double-check the RF3 files.

A digital raster graphic (DRG) is a scanned image of a USGS topographic map. This image is georeferenced to the earth and can be used to collect, review, and revise other digital data, especially digital line features. In addition, the maps are produced at the 1:24,000 scale (as compared to the 1:100,000 scale RF3), which gives a more detailed representation of the land surface (USGS, 1999). A sample image is shown in Figure 3.6.

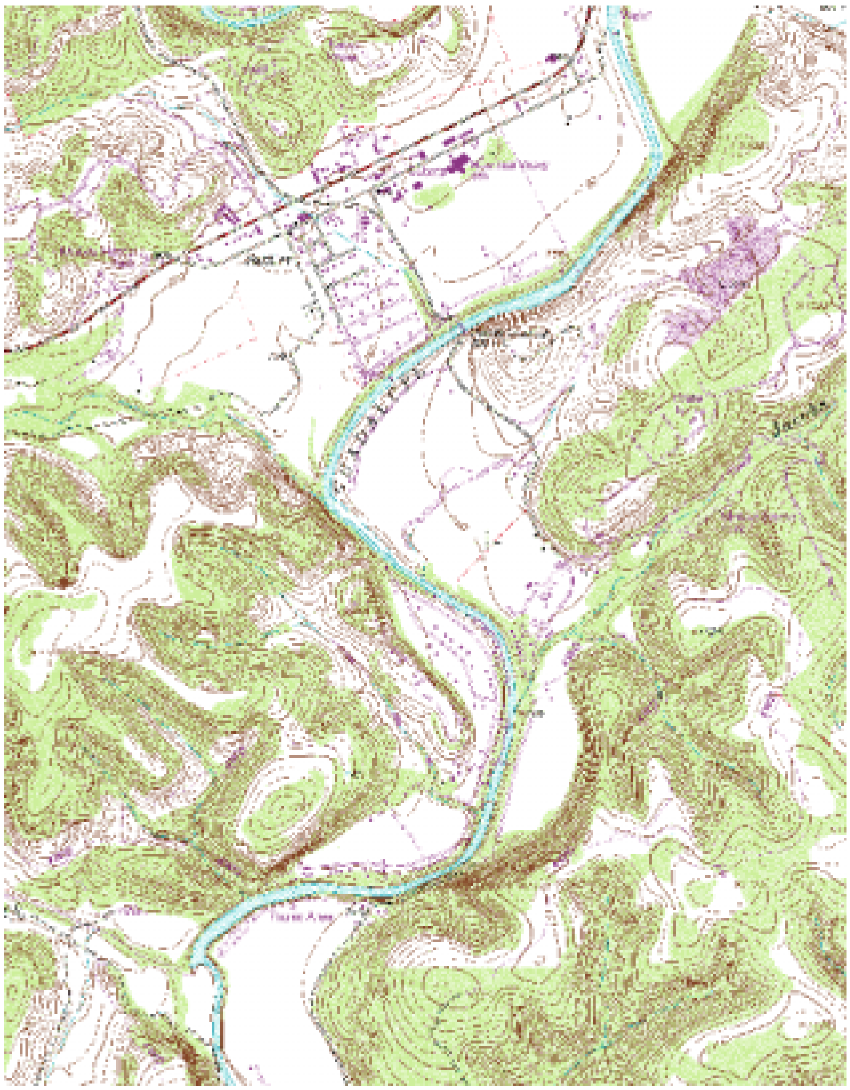

Figure 3.6: Sample USGS digital raster graphic (USGS, 1999)

Once the USGS topographic paper map is scanned, the digital image is georeferenced to the true ground coordinates and projected to the Universal

Transverse Mercator (UTM) for projection consistency. The original datum (normally North American Datum 1927) is preserved in the DRG (USGS, 1999).

3.3.5 Precipitation Grids

In order to calculate how much water is available for a given water right, information about mean annual precipitation in the drainage area is needed. For the purposes of this research, a gridded representation of rainfall was the most useful. Therefore, the Oregon State PRISM climate grids (which are GIS-compatible) were chosen as the best source of climatic information. Below is an image of rainfall variation across the state of Texas.

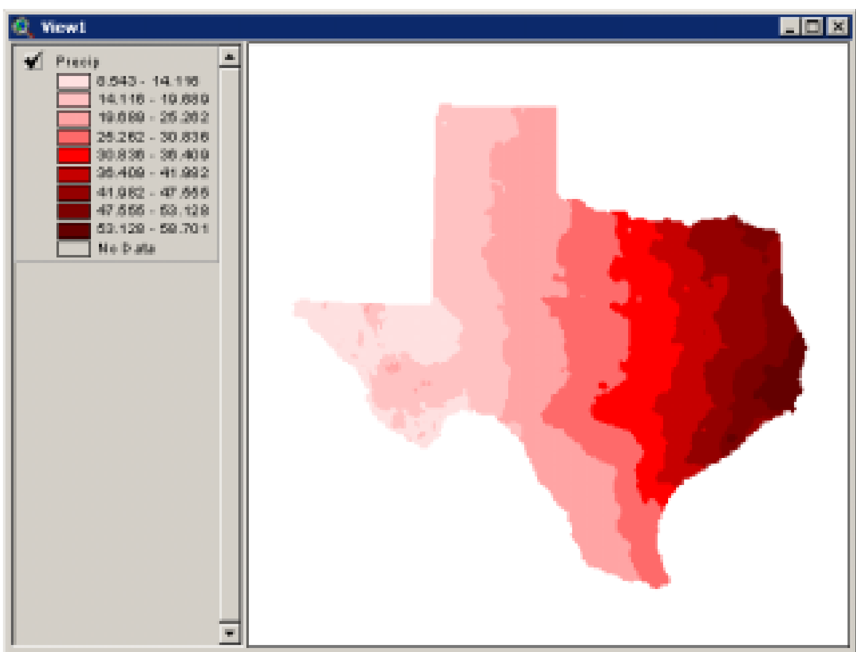

Figure 3.7: PRISM average annual rainfall grid for Texas

PRISM (Parameter-elevation Regressions on Independent Slopes Model) is an analytical model that uses point data and a DEM to generate gridded estimates of monthly and yearly climatic parameters. More importantly, PRISM has been used extensively to map precipitation across the entire United States in a spatially representative and physically meaningful way. The resulting precipitation layer has physically realistic detail and has a national spatial extent (Daly, 1996).

3.3.6 Curve Number Grids

Finally, the last data set needed was the Soil Conservation Service Curve Number grid. A curve number is a value (ranging from 0-100) that represents the ability of the land surface to capture water. A low curve number means that water easily infiltrates into the soil, leaving less for run-off. A high curve number means the water is not captured by the land surface, but instead turns into run-off.

The Blacklands Research Center in Temple, Texas provided the Curve Number grid that was used in this research. Using the USDA/NRCS STATSGO soil coverage with the USGS LULC coverage, the Blacklands Research Center generated a 250-m resolution grid by combining the soil and land values into curve numbers using the 1972 SCS Engineering Hydrology Handbook as a reference (Hudgens, 1999).

3.4 MAP PROJECTIONS

Choosing the proper map projection to work with all the data files was a core issue at the outset of this project. Maps, of course, are 2-D representations of 3-D surfaces. The process of projecting curved surfaces onto flat maps inevitably distorts one or more properties of the land features – shape, area, distance, etc. Therefore, a need existed not only for a consistent map projection to work with the files, but also a map projection that would preserve area when performing drainage area calculations.

Fortunately, Texas had already defined a consistent map projection for use throughout the state: Texas State Mapping System (TSMS). Since TSMS Albers preserves true earth surface area for polygons, it was chosen as the coordinate system for all project deliverables. Table 3.1 shows the projection attributes.

Parameters	**TSMS Albers**
Projection	Albers
Datum	NAD 83
Spheroid	GRS1980
Units	Meters
Standard Parallel 1	27 25 00
Standard Parallel 2	34 55 00
Central Meridian	-100 0 00
Reference Latitude	31 10 00
False Easting	1000000
False Northing	1000000

Table 3.1: TSMS Albers map projection parameters

However, one of the main files used in the stream editing procedure was the digital raster graphics. These files were retrieved from TNRIS in the Universal Transverse Mercator (UTM) projection, which consists of a sequence of 6-degree zones covering the globe. Three of these zones (13, 14, and 15) cover the State of Texas. Zones 14 and 15 cover the 4 basins studied in this research. Originally, an attempt was made to project the DRG files into the TSMS albers projection so that they would overlay with the remainder of the files. Unfortunately, the DRG files were far too large and very time consuming to project. So, during the editing process, the stream network and point coverages had to be projected into UTM to perform the required edits before being projected back to TSMS albers for the final processing. Table 3.2 shows the UTM projection parameters.

Parameters	**UTM**
Projection	UTM
Zone	14 or 15
Datum	NAD 27
Spheroid	Clarke 1866
Units	Meters

Table 3.2: UTM map projection parameters

3.5 CONCLUSION

Many different data sets were required for this research. The next chapter describes the steps taken to compute the watershed parameters for all the water right locations within the study basins.

CHAPTER 4: PROCEDURE

4.1 INTRODUCTION

At the outset of this research, a general procedure for developing a spatial water rights database had already been established by Hudgens (1999). This chapter contains an overview of this procedure, which leads into a description of the changes made to improve the methodology and results in the case studies to follow. Figure 4.1 is a simple flow chart of the project tasks discussed.

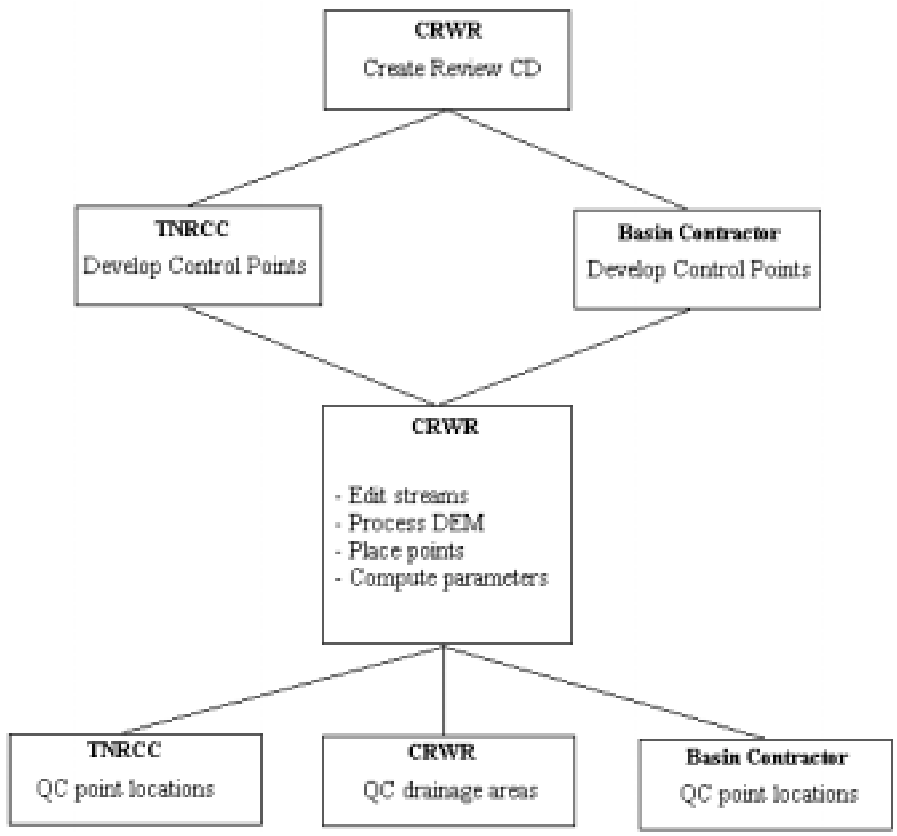

Figure 4.1: Project flow chart.

Chapter 4 is divided into 5 sections. The first section discusses the development of the control point coverages to be used in the modeling. Section 2 describes the processes used to develop the basin stream network. The third section details the methods used to process the DEM in preparation for drainage area calculations. Then, section 4 shows how all the watershed properties are calculated and compiled. Finally, the fifth section explains the quality control techniques used to ensure accurate results. This chapter is simply an overview of the database development procedures. For a detailed, step-by-step description of the database development, see Hudgens (1999) at http://www.crwr.utexas.edu/crwr/reports/rpt99_4/rpt99_4.html.

4.2 DEVELOPING THE BASIN CONTROL POINTS

One of the key elements in this research was obtaining accurate locations of all the model control points for each of the river basins. The model control points consist mainly of water rights, diversion locations, stream gages, and return flow locations. Since the control points were developed by various parties (both TNRCC and the basin contractor), the first task was to compile a common set of files for each party to use. Thus, CRWR provided both TNRCC and the basin contractor with a location review cd-rom that contained all of the working files needed to establish the control point locations. The following is a list of files contained on the cd-rom:

- Master water rights file
- Stream gage locations
- River reach file (RF3)
- Basin coverage
- County coverage
- 7.5-minute quadrangle mesh
- DRGs

The master water rights file consists of a GIS coverage of all the water right locations in the basin. However, each water right may have several diversion locations associated with it. These diversions consist of return flow locations, on-channel reservoirs and off-channel reservoirs. Figure 4.2 shows an example of a master water right and its associated diversions.

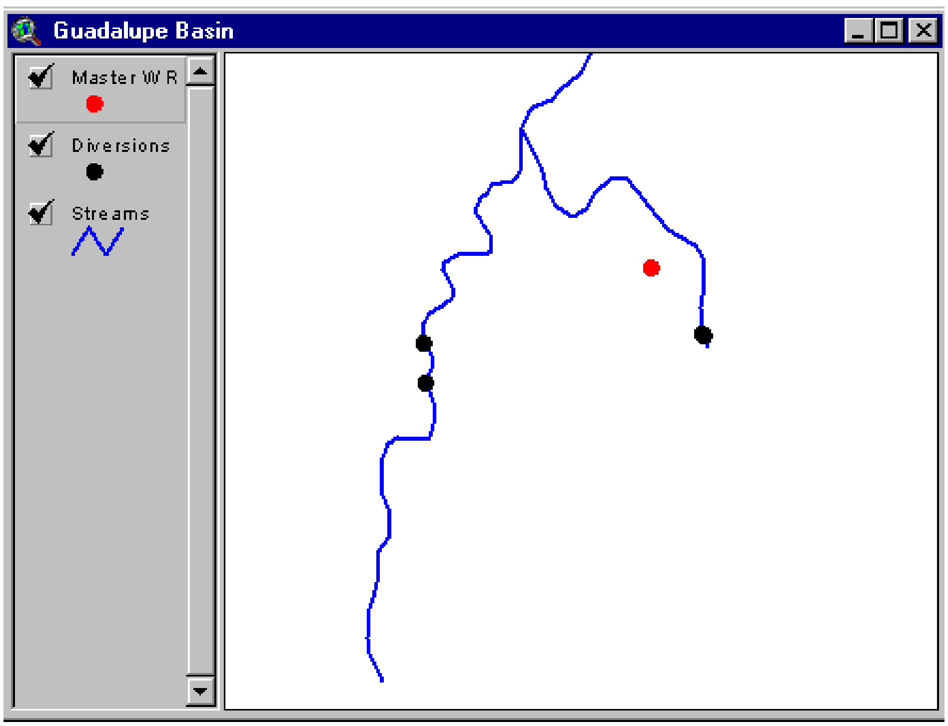

Figure 4.2: Master water right with diversions

Since CRWR does not have access to the water right permits defining these diversions, it becomes the task of the TNRCC to locate all of these points. Therefore, TNRCC uses the location review cd-rom to check the water right locations against their records, and then edits the water right coverage accordingly. Once the editing process is completed, the new water rights coverage is returned to CRWR for further processing. This step will be discussed later.

The basin contractor has the ultimate responsibility of determining which points will be modeled. Thus, once the water right locations are set, the contractor delivers the additional points needed for the modeling. These points usually consist of known flow locations, such as USGS stream gages. Other points included throughout the project were additional return flow locations and locations along aquifer recharge zones. Unlike the coverages received from TNRCC, these points usually were delivered in spreadsheet format (Table 4.1).

Gage #	Lat	Long	Area (mi^2)
8067650	30°20'31"	095°32'34"	451
8068000	30°14'40"	095°27'25"	828
8068500	30°06'37"	095°26'10"	409
8068740	29°57'32"	095°43'03"	131
8069000	30°02'08"	095°25'43"	285
8069500	30°01'37"	095°15'28"	1741
8070000	30°20'11"	095°06'14"	325
8070500	30°15'34"	095°18'08"	105
8071000	30°13'57"	095°10'05"	117
8071500	29°59'40"	095°08'00"	2800
8073500	29°45'42"	095°36'20"	293
8074000	29°45'36"	095°24'30"	N/A
8074500	29°46'30"	095°23'49"	86.3
8075000	29°41'49"	095°24'43"	94.9
8075500	29°40'27"	095°17'21"	63
8076000	29°55'05"	095°18'24"	68.7

Table 4.1: Contractor identified control points for San Jacinto Basin

As shown in Table 4.1, each gage was located by a latitude and longitude. Using these locations, a point coverage was generated in Arc/Info that was then overlaid on the basin files to check for proper location. In most cases, this method was sufficient to properly determine the exact location of the point. However, in some instances, the points fell in areas without streams or even outside the basin. Also, if a point fell near a junction, it was essential to know exactly which tributary the point should be on to ensure that proper parameters are calculated later. Thus, the DRGs on the location review cd-rom became a valuable tool for both CRWR and the basin contractor in the communication of these problems. Often the contractor would send a photocopy of the corresponding USGS paper map with the exact location of the point drawn on the map. With this in hand, CRWR was able to place the point properly.

Another task in developing the basin control points was the establishment of a unique identifier for each point. Originally, each water right was identified by its permit number, which was usually a 5-digit integer. However, with the addition of diversion points associated with these water rights, a new identification system had to be developed. With the assistance of TNRCC, the following scheme was used: BBTWWWWWDDD where,

- T = type (1 or 6)
- BB = basin number (01 to 23)
- WWWWW = water right permit number
- DDD = diversion point number
    - 001 – 099 = diversion point
    - 101 – 199 = upstream limit of segment
    - 201 – 299 = downstream limit of segment
    - 301 – 399 = on-channel reservoir
    - 401 – 499 = off-channel reservoir
    - 501 – 599 = return flow

The T represents the type of water right, with the 1 representing adjudications and the 6 representing permits. BB stands for basin number. Each basin assigned a number according to the following table (4.2).

Basin	#	Basin	#	Basin	#
Canadian	1	Trinity-San Jacinto	9	Lavaca-Guadalupe	17
Red	2	San Jacinto	10	Guadalupe	18
Sulphur	3	San Jacinto-Brazos	11	San Antonio	19
Cypress	4	Brazos	12	San Antonio-Nueces	20
Sabine	5	Brazos-Colorado	13	Nueces	21
Neches	6	Colorado	14	Nueces-Rio Grande	22
Neches-Trinity	7	Colorado-Lavaca	15	Rio Grande	23
Trinity	8	Lavaca	16		

Table 4.2: Basin numbers

This system was able to accommodate most points used in the process. However, USGS ID's remained the same for USGS stream gages and basin contractor points were numbered as per their request.

4.3 DEVELOPING THE BASIN STREAM NETWORK

One of the most critical and labor intensive portions of the database development was the creation of the basin stream network. In order to calculate watershed parameters, a single-line representation of the basin hydrography was needed for use in defining a channel network within the DEM. Fortunately, EPA had developed the RF3 that provided a starting point for this process. However, as stated in Chapter 3, many errors and gaps exist in these files. Also, the RF3 files contain all elements of the basin hydrography, including rivers, lakes, reservoirs, and canals. Some of these features can interfere with the goal of developing a single-line stream network. Therefore, for each river basin, an extensive process of editing and revising had to be performed.

The RF3 files were downloaded from the EPA Basins website at http://www.epa.gov/ostwater/BASINS/gisdata.html. At the website, the files are divided into 8-Digit Hydrologic Unit Codes (HUCS). Once downloaded, all the required files were merged to establish the basic stream network for the entire basin.

4.3.1 Editing the Stream Network

A single-line network is defined as a network of streams in which only a single flow path exists from each headwater to the outlet of the basin. This type of network is required to accurately represent the drainage features of the basin. Also, in later stages, a single-line network can easily be navigated in order to determine the connectivity of each point (i.e. which point is downstream or upstream of another).

The first step in the editing process was to query out all the irregular features of the network using Arcview. Figure 4.3 shows the command used.

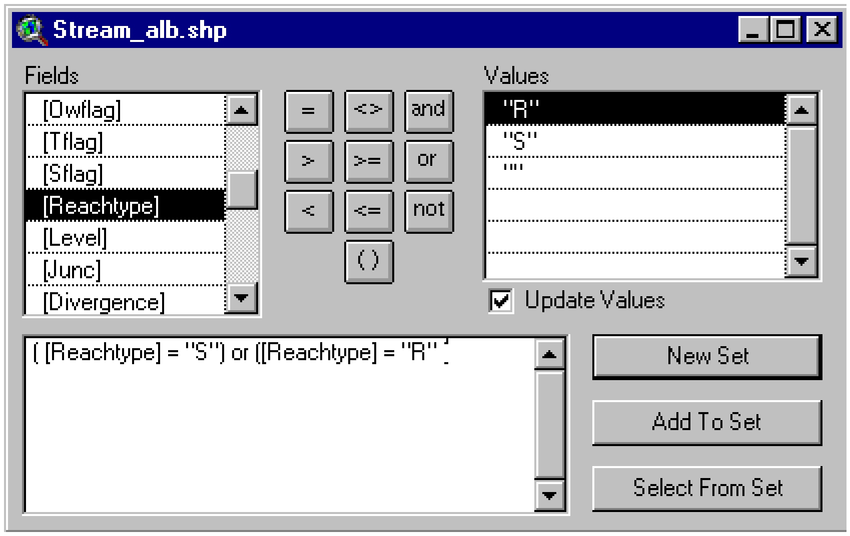

Figure 4.3: Query function for eliminating unwanted features in RF3

The "S" reachtype refers to "start" reaches while the "R" reachtype refers to regular reaches. Once selected, a new shapefile is created from these two features while all others are deleted. This process eliminates all open water features, such as lakes, reservoirs, and shorelines. It also eliminates double-line features, which occur when both sides of wide river sections are delineated in RF3. Although deleting these features is helpful, it also creates new problems.

With only start and regular reaches remaining, gaps in the network now existed where the unwanted features were deleted. Figures 4.4 and 4.5 display an example of how these gaps were created. Once the lakes were deleted, there was nothing remaining to connect the two streams.

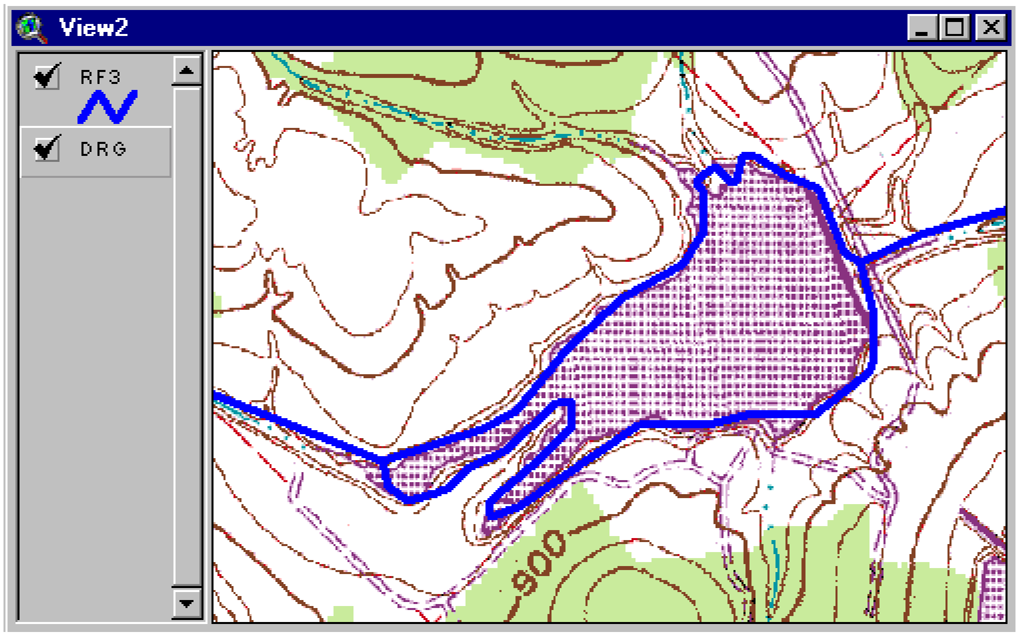

Figure 4.4: RF3 before editing

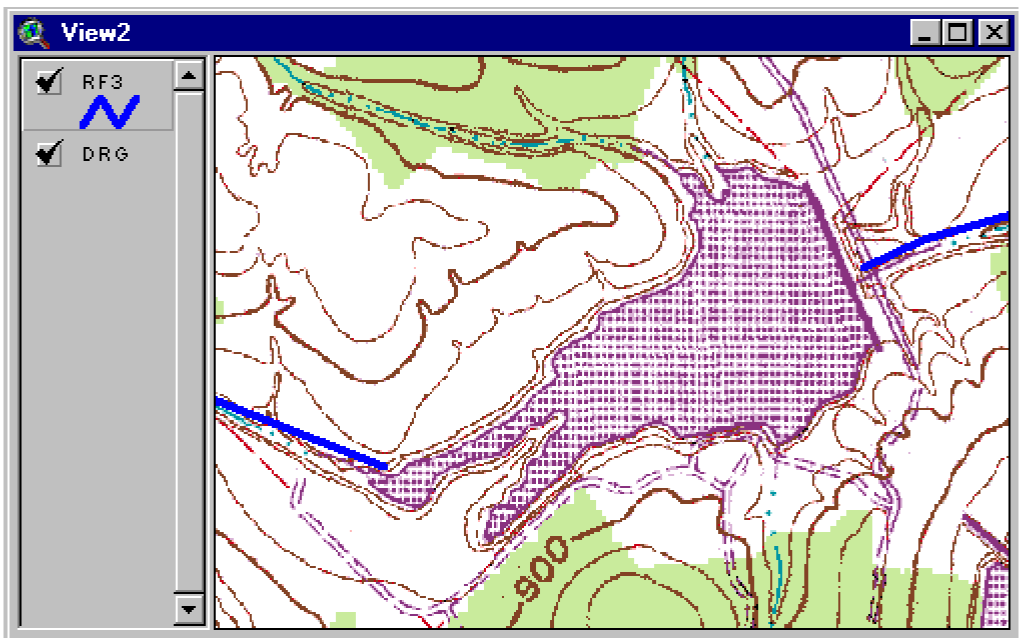

Figure 4.5: Disconnect in RF3 after removing open water features

In order to rectify such a problem, the gap had to be filed by a line representing the flow path through the open water feature. Overlaying the stream network on the DRG files (as shown in Figures 4.4 and 4.5) helped with this process. Originally, this step was performed by hand using the editing tools within Arcview. However, during this project, USGS developed a “centerline” file as part of the NHD development that contained flow paths for most of the open water features in the state. This eliminated the hand-delineation process, but it was still necessary to ensure that the endpoints of the centerline were attached to the RF3 network. Also, many of the gaps remaining from small, on-channel lakes were not included in the USGS centerline coverage and still had to be filled by hand. An example of an open water feature filled by a USGS centerline is shown in Figure 4.6.

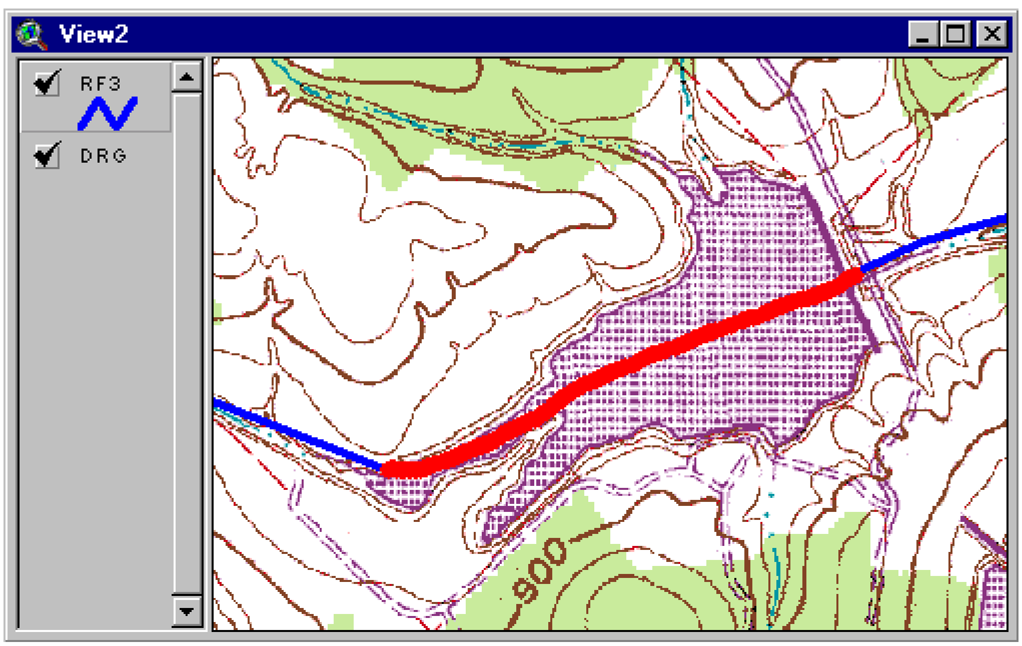

Figure 4.6: Reservoir transport path (red) from USGS centerline file

Gaps and open water features were not the only issues to be concerned with in the editing process. Braided stream networks also presented problems when trying to develop a single-line stream network. Braided streams occur in marshy areas where the river's flow can be diverted through a variety of paths. Again, for this research, only a single path was needed. Therefore, using best judgment, the most well defined path was chosen as the transport section through the braided area, and all others were deleted. Figure 4.7 displays an example of a braided network and the corrections made.

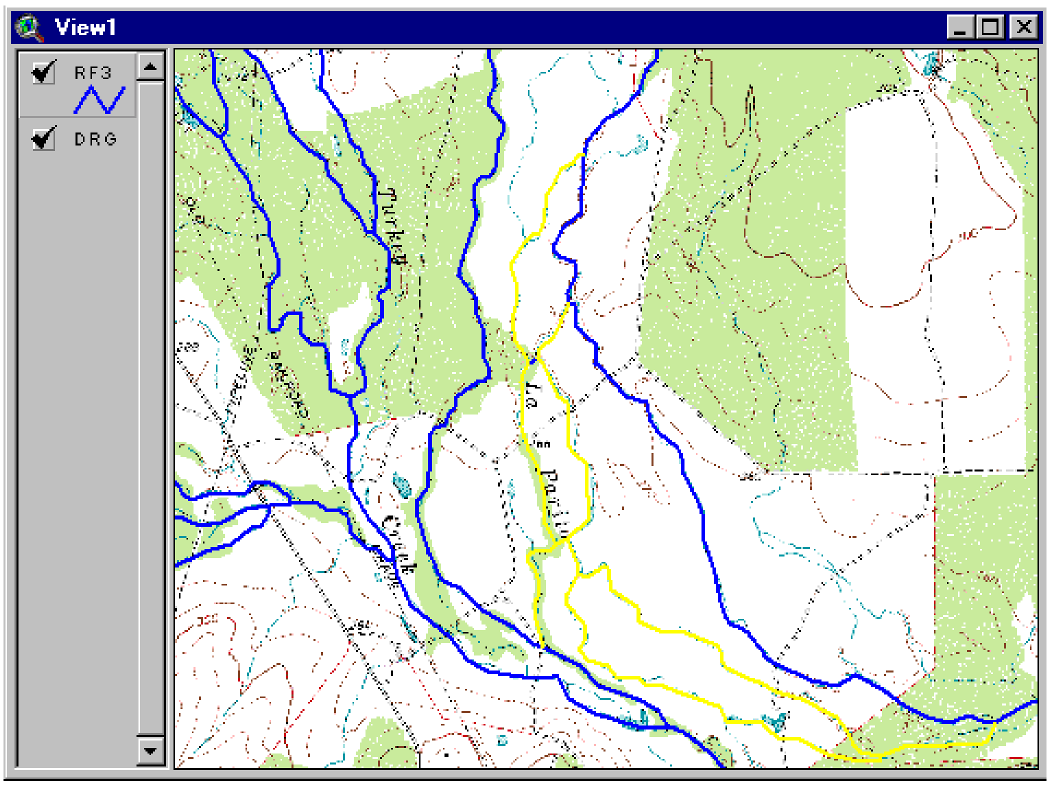

Figure 4.7: Braided stream section with highlighted reaches (yellow) to be deleted

Another problem to be addressed when editing the stream network was the issue of closed loops. Closed loops occur when part of the channel's flow is diverted and then reconnects downstream, or to another reach within the network. In many instances, a closed loop did not affect the overall drainage of the river network since the flow direction step of the DEM processing (discussed in Chapter 4) chooses the steepest drainage path. However, there were cases in which a control point was located on either the diverted stream or a section of the river downstream of the diversion point. Since this would result in either an overestimation or underestimation of that point's drainage area, a decision had to be made as to which path most accurately defined the network. Again, this became a judgment call on the part of the researcher. Figure 4.8 is an example of a closed loop within the stream network.

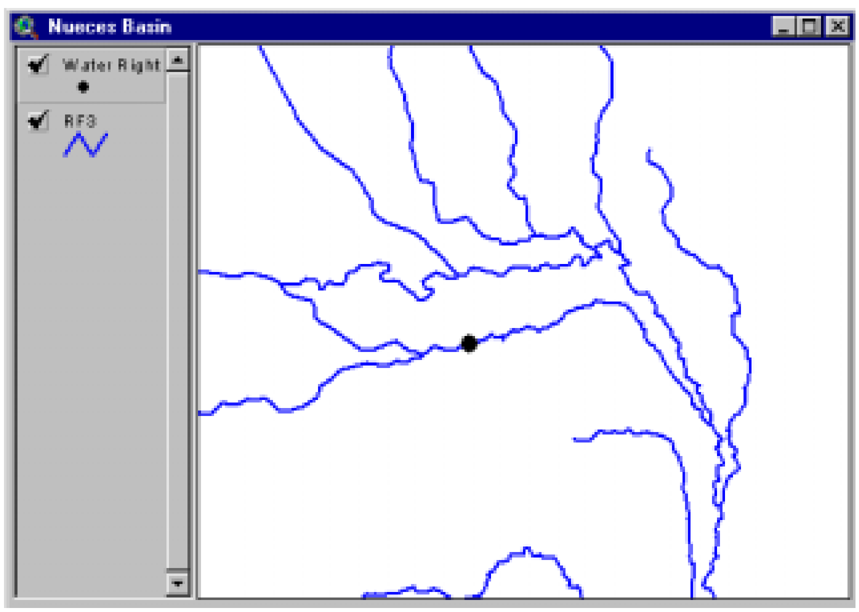

Figure 4.8: Water right within stream loop

4.3.2 Adding Streams to the Network

Although RF3 provided a solid foundation for building a stream network, it has been shown that many deficiencies still exist. Not only were there unwanted features, but the opposite problem existed in that there were also many streams that simply were not included in the file. This fact became particularly apparent upon receipt of the control point coverages from TNRCC and the basin contractor. The reason for the missing streams was that both parties used the 1:24,000 scale DRGs as a reference to place the control points. However, since RF3 was created at the 1:100,000 scale, it did not represent all the minor streams shown on the DRGs. Therefore, by overlaying the stream network on top of the DRG, the missing streams needed to connect the points to the stream network were found. Once the streams were located, new streams were digitized from the DRG and added to the single-line stream network using the editing tools in Arcview.

Figure 4.9 shows an area where it was necessary to add streams that did not exist in RF3. As shown, not only was it necessary to add the stream upon which the point is located, it was also important to digitize any surrounding streams. Subtle changes in the land surface can be lost in its conversion to grid format, depending on the resolution of the DEM. Therefore, adding the surrounding streams can help to more clearly define the drainage area of small tributaries.

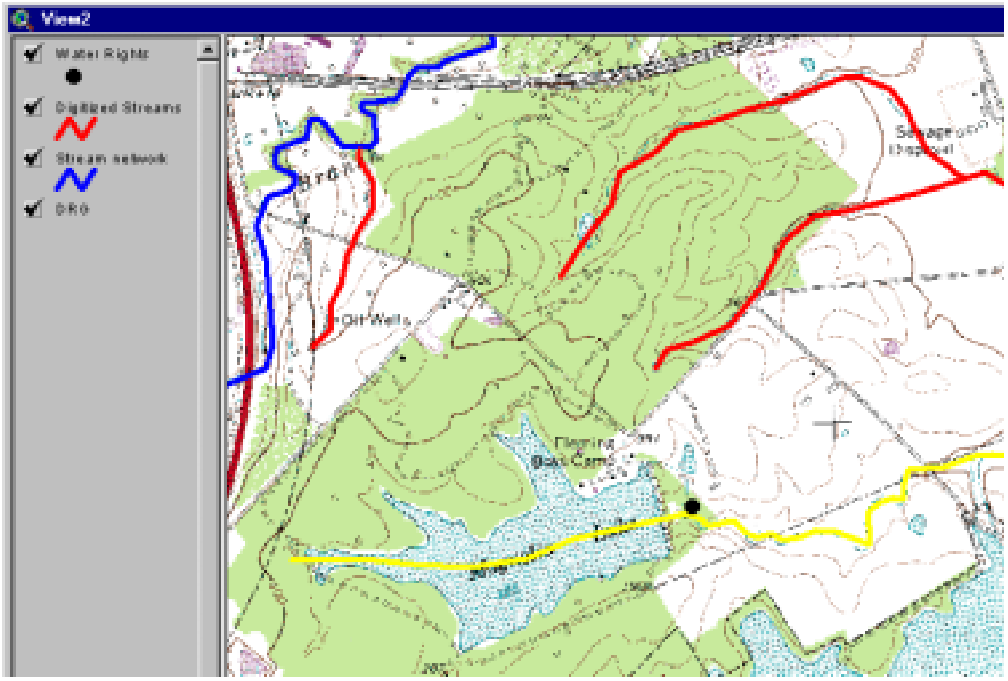

Figure 4.9: Manually digitized (red & yellow) streams added to original *RF3 (blue)*

4.4 PROCESSING THE DEM

Once a valid, single-line network was created, the next step was to develop and process the DEM for the basin. At the inception of this project, the best available DEMs were at the 1:250,000 scale, which contained elevation data at 90-meter intervals. The DEM data was stored at the USGS website (http://edcwww.cr.usgs.gov/glis/hyper/guide/1_dgr_demfig/index1m.html) in 1 degree by 1 degree boxes. The appropriate files covering the basin were downloaded from the website and merged together to form one file. Before clipping the merged file to the extent of the basin, a 10-kilometer buffer was added to the basin boundary in order to capture the drainage features just outside of the basin. An example of the DEM file for the San Jacinto basin is shown in the Figure 4.10.

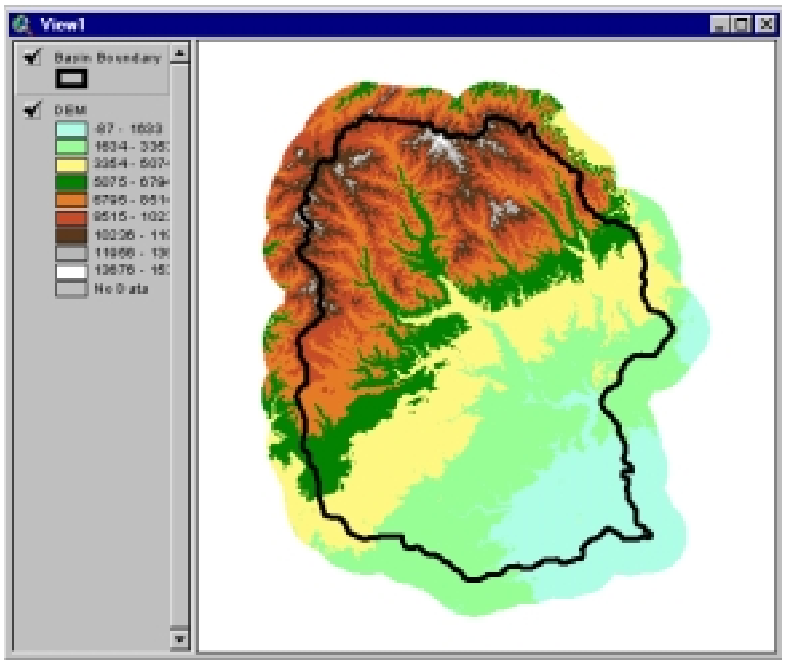

Figure 4.10: San Jacinto basin DEM with basin boundary

After creating the DEM, the file was then processed using an Arcview extension, CRWR-PrePro, that had been previously developed by the researchers at CRWR. The first step in the process is called “burning the streams.” The stream burning process involves raising all the grid cells surrounding the stream network by a specified elevation. Essentially, a channel is built in the DEM that exactly matches that of the stream network. The elevation to raise the grid cells must be chosen so that it is greater than any other point on the original DEM. Once the stream network is embedded into the DEM, the second step in CRWR-

PrePro, filling, is performed. The filling process searches the DEM for small sinks and pits. Since these pits can unnecessarily capture water in the terrain, they must be filled by raising the elevation of the pits to that of the surrounding cells. After burning and filling, the resulting grid is then run through the flow direction process. In this step, the flow direction of each cell in the grid is determined by examination of the elevations in each surrounding cell. Thus, the steepest slope determines the cell's flow direction. This process is needed to determine the areas of the terrain that flow into each stream. The final step in CRWR-PrePro is the flow accumulation process. This function uses the newly created flow direction grid to determine the number of upstream cells above each point in the basin. Throughout the basin, each cell is assigned a value that is representative of all the cells draining to that point. Thus, a greater cell-count refers to a larger drainage area. Figures 4.11 and 4.12 show the flow direction and flow accumulation grids, respectively.

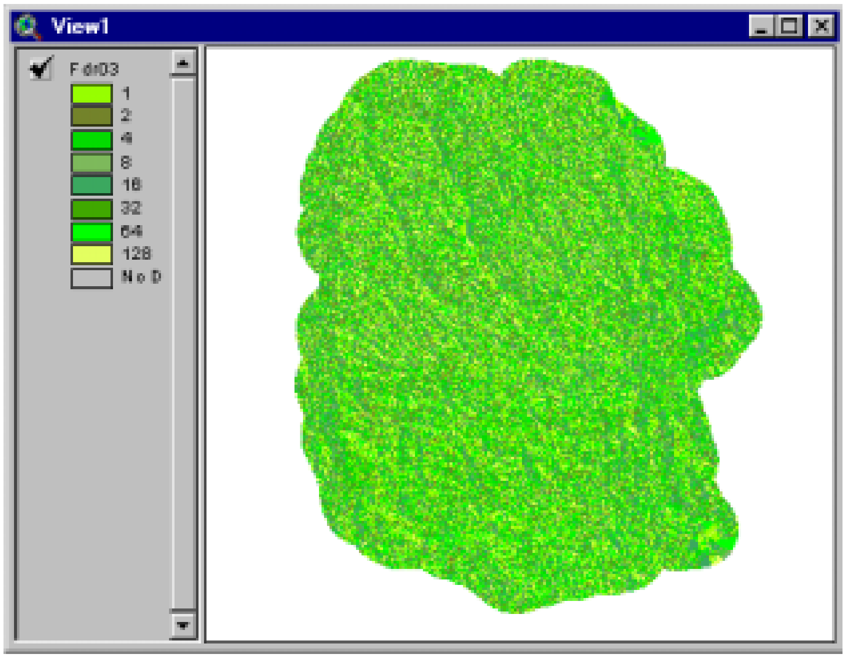

Figure 4.11: Flow direction grid of San Jacinto basin

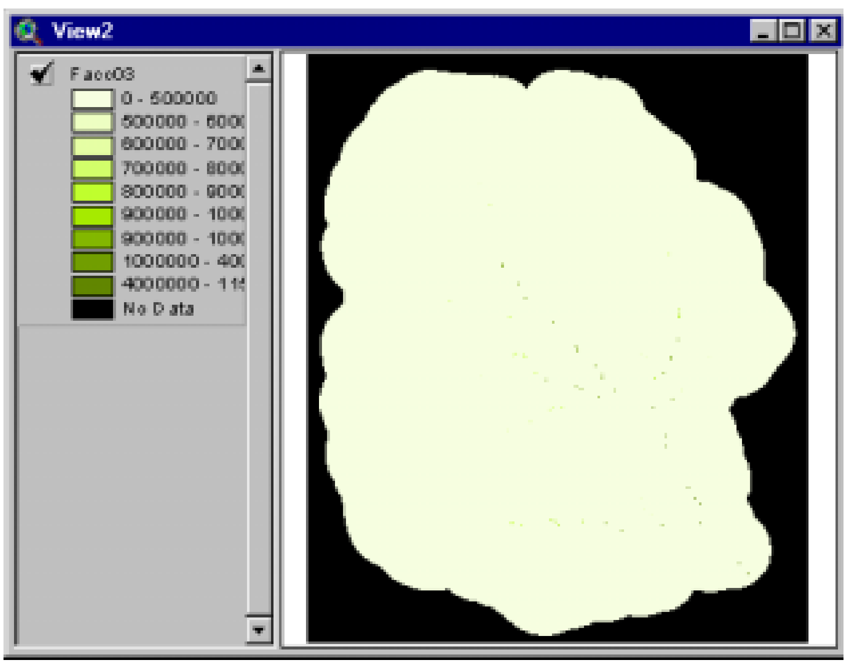

Figure 4.12: Flow accumulation grid of San Jacinto basin

4.5 COMPUTING THE WATERSHED PARAMETERS

The processed DEM files form the basis for the watershed parameter calculations. The drainage area for each point was calculated from the flow accumulation grid. Also, using the grid program within Arc/Info, the basin precipitation and curve number grids were combined with the flow direction and flow accumulation grids to compute the average precipitation and curve number grids. The third parameter, next downstream point, was found by simply checking each point by hand. This section details these procedures.

4.5.1 Calculating Drainage Area

As stated, the flow accumulation grid calculates the number of cells in the basin flowing to each point. Thus, by checking the flow accumulation value at a point, only a simple calculation is needed to find the drainage area.

$$\text{Drainage Area (mi}^2) = \frac{\#\text{ of cells} \times \text{cell size}^2\ (\text{m}^2)}{2589988\ (\text{m}^2/\text{mi}^2)} \qquad \text{(Eqn. 4.1)}$$

However, the main issue in this process was ensuring that the control points were located on the appropriate flow accumulation grid cell. Initially, the points had only been placed on the stream network. However, at the end of the DEM processing, the stream network may no longer fall along the path of the flow direction grid. This happens when the stream network crosses more than one cell at a time while the flow direction function can only choose one path. Figure 4.13 shows such an example.

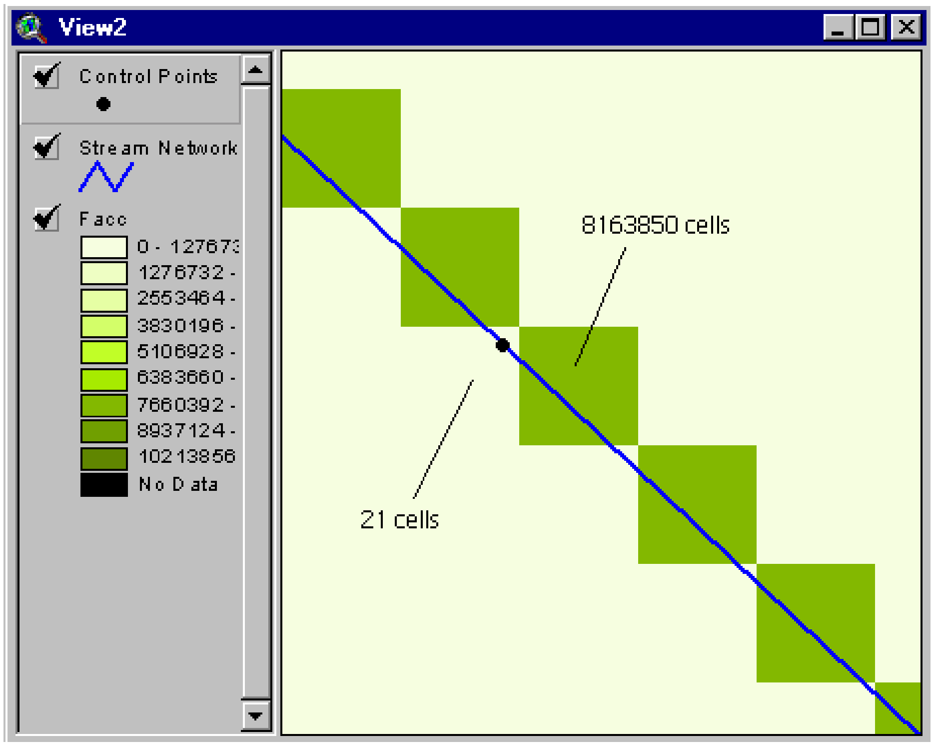

Figure 4.13: An incorrectly located control point

As shown, an incorrectly located control point can result in a drastic error in reported drainage area because the point location does not lie over a grid cell on the stream network. In the present location, a drainage area of 0.01 square miles would be reported, rather than the true area of 2837 square miles (8163850 cells of 30-meter size). At the time, the solution to this problem was to check each point by hand against the flow accumulation grid to determine its proper location. However, over the course of the project, an automated system was set up to correct these types of problems. This method will be presented in the case study of the San Jacinto basin.

4.5.2 Calculating Average Curve Number and Precipitation

Along with drainage area, the two other parameters needed for each point were the average curve number and average precipitation across the control point watershed. As with the DEM, curve number and precipitation grids already existed for the state. Therefore, in order work with them, they simply had to be clipped to the spatial extent of the basin boundary. The only difference in this step was that the existing CN and precipitation grids were sampled at different resolutions than the DEM. So, before proceeding, each grid had to be resampled to the same cell size and extent of the basin DEM. The following Arc/Info commands serve this purpose (Note: Words in all caps represent generic file names):

*Grid***: setcell DEM DEM**
*Grid***: setwindow DEM**
*Grid***: NEWPRECIP = PRECIP**
*Grid***: NEWCN = CN**

At this point, each of the new grids has the same cell size as the DEM. However, the extent of the new grids is still that of the original grids (i.e. the entire state). In order to continue working with the parameter calculations, the grids first have to be resized to that of the basin. Using a conditional function in Arc/Info, the flow direction of each cell was queried. If the value of the flow direction grid was greater than zero, the corresponding cell in the precipitation and/or CN grid was kept. This ensured that only the precipitation and CN grid cells within the basins were kept, thus creating a grid that exactly coincided with the flow direction grid. The following Arc/Info commands were used in the resizing:

Grid: **NEWPRECIP = con (FDR > 0, NEWPRECIP)**
Grid: **NEWCN = con (FDR > 0, NEWCN)**

The final step in calculating curve number and precipitation values for the control points was to create a weighted flow accumulation grid from the newly created precipitation and CN grids. Mathematically, an average CN or precipitation over several areas can be calculated by performing a weighted average (i.e. dividing the sum of the products of each area and parameter by the total area). Therefore, the same idea can be applied when working with grids. To find the average CN of a certain location, the sum of the products of each upstream cell and its CN value is divided by the total number of cells in that location's drainage area. The following Arc/Info command was used to create the average CN grid for the basin.

Grid: **AVGCN = (flowaccumulation (FDR, NEWCN) + NEWCN) / (FACC + 1)**

By substituting the precipitation grid in place of the CN grid, the average precipitation grid for the basin was calculated in a corresponding manner.

4.5.3 Reporting the Control Point Parameters

With the control points in place, and all required grids calculated, the final step was to produce a table of watershed parameters for each point. In the early stages of this project, the parameter table was created by manually checking each control point and inserting its corresponding parameters into a table. However, with hundreds of control points to consider, this method proved to be quite tedious and time consuming. A script written by Patrice Melancon was able to query raster files at the same location of a point and insert the grid values into a table. Thus, this script was modified by Brad Hudgens to incorporate the needs of the WAM team. The output of this script was a new control point coverage with the values of drainage area, average CN and average precipitation in the attribute table. The following is an example of the parameter attribute table.

Parameter Table

Shape	Id	Type	Dem_fac	Area (mi^2)	Avg_cn	Avg_precip
Point	831200	Stream gage	728004	232.07	62	41
Point	832000	Stream gage	3591005	1144.74	62	42
Point	832500	Diversion point	6094270	1942.74	64	43
Point	833000	Stream gage	8544864	2723.94	65	43
Point	833500	Stream gage	11390380	3631.04	64	44
Point	833900	Stream gage	493185	157.22	62	45
Point	834500	Stream gage	1180284	376.26	71	47
Point	836500	Stream gage	3994834	1273.48	68	45
Point	837000	Stream gage	5023212	1601.30	68	45
Point	838000	Stream gage	1580651	503.88	65	48
Point	839100	Stream gage	279454	89.08	66	50
Point	840600	Stream gage	23750624	7571.24	65	45

Figure 4.14: Excerpt of parameter attribute table

Along with the attribute table, watershed delineations had to be produced for each of the control points in the basin. Again, CRWR-PrePro was used for this task. The extension reads the flow direction grid upstream of each point and draws a boundary around the area flowing to that location. If a point exists upstream, the extension produces an incremental watershed between the two points.

4.6 EVALUATING THE QUALITY OF PARAMETERS

Since many of the parameter calculations were performed in an automated fashion, a great deal of effort was spent on quality control. First, an evaluation was made as to which parameter was the most important factor in producing accurate results. As stated, both the CN and precipitation values were based on weighted averages using the control point drainage areas. Since there was no legitimate way to modify the accuracy of the original CN and precipitation grids themselves, it became clear that the drainage area calculations were the most sensitive parameter within the methodology. Also, enhancing the accuracy of the drainage areas would consequently improve the average CN and precipitation values. Clearly, it would be impossible to check the drainage area for each point in the basin. Therefore, a method had to be devised that would cover a representative, yet manageable amount of data.

The first check performed for quality control was the evaluation of the stream gages and other known flow locations. USGS records contain drainage area values for each stream gage location. Therefore, it was a simple task to check the model drainage areas against the widely accepted USGS values. Also, the respective basin contractors provided drainage area values for known flow points in the basin to be modeled. Table 4.3 shows a comparison of drainage areas for the Nueces basin stream gages and known flow control points (in this case, known flow values were provided by HDR, Inc).

Control Point		Known Area (mi^2)		Relative	
ID	Area (mi^2)	USGS	HDR	Difference	% Error
1	757.34	737		20.34	2.76
2	687.56	694		-6.44	-0.93
3	1863.73	1861		2.73	0.15
4	4158.02	4082		76.02	1.86
5	5307.64	5171		136.64	2.64
6	8284.85	8093		191.85	2.37
7	393.95	389		4.95	1.27
8	124.32	126		-1.68	-1.33
9	638.16	631		7.16	1.13
10	33.94		36	-2.06	-5.72
11	31.77		32	-0.23	-0.72
12	209.68	206		3.68	1.79
13	248.03	241		7.03	2.92
14	18.02		18	0.02	0.11
15	4.37		6	-1.63	-27.17
16	45.48	45		0.48	1.07
17	165.23	168		-2.77	-1.65
18	97.59	96		1.59	1.66
19	153.39	149		4.39	2.95
20	12.00		12	0.00	0.00
21	57.57		55	2.57	4.67
22	104.93		105	-0.07	-0.07
23	47.21		47	0.21	0.45
24	138.99	Spring		N/A	N/A
25	3431.05	3429		2.05	0.06
26	784.33	783		1.33	0.17
27	5480.88	5490		-9.12	-0.17
28	1158.43	1171		-12.57	-1.07
29	15628.00	15427		201.00	1.30
30	16722.87	16660		62.87	0.38
31	16986.07	16920		66.07	0.39

Table 4.3: Drainage area comparison for Nueces basin control points

As shown, a majority of the points fall within a relative difference of approximately 1 to 2 percent. However, these very small percentages hide large discrepancies in total drainage area. For example, control point 29 shows a difference of only 1.30%, but the actual values differ by over 200 square miles.

The watersheds for points such as this were checked against the DRG topography to rectify these errors. Reasons for such discrepancies included errors in the stream network and deficiencies in the 1:250,000 scale DEMs to represent terrain relief in the flatter areas of the basin. Solutions to these problems will be presented in the case studies to follow.

The second step in the quality control process was to check the smaller watersheds in the basin. Experience with watershed delineations from 1:250,000 scale DEMs revealed that areas with a flow accumulation of less than 1000 cells contained a high probability of delineation areas. Elevation data at 90-meter intervals was simply not sufficient enough to represent changes in topology of small areas. Therefore, each watershed below 1000 cells in size was checked visually against the DRGs. If a discrepancy was found, a new watershed was digitized manually with the editing tools in Arcview. The validity of the 1000 cell threshold is discussed in the results section of this thesis

4.7 CONCLUSION

The steps presented in this chapter represent an overview of the methodology used at the outset of this research. Using data compiled by CRWR, TNRCC and the basin contractor developed the control point coverages to be modeled for the basin. During this time, a single-line stream network was constructed from the EPA's RF3 file. Once the points were returned, the location of each was checked against the newly created stream network. If a point was not on the stream network, the location was verified against the DRGs and a new stream was digitized into the network. After the final stream network was completed, the DEM was processed using the CRWR-PrePro extension in Arcview. The next step was the development of the average CN and precipitation grids. A script was then run to extract all the parameters for each control point. Finally, an extensive quality control procedure was performed to check the accuracy of the results.

The methods described in this chapter provide the basis for all the work performed in this research. However, as problems were encountered, the process was changed to eliminate shortcomings in the methodology and to improve the overall accuracy of the results. The next 3 chapters entail case studies of each river basin in the study area.

CHAPTER 5: CASE STUDY – NUECES BASIN

5.1 INTRODUCTION

The Nueces river basin is located in South Texas (see location map in the study area section of Chapter 1) and services all or parts of 22 counties, with its rivers and tributaries draining an area of approximately 17,000 square miles. The basin contractor for the Nueces was HDR, Inc, located in South Austin. At the outset of the study, HDR decided that it did not need precipitation and curve number information, but would instead need flow length values for each point. These flow length values would be used to calculate channel losses in order to distribute known flows throughout the basin. Other than this change, the first processing run followed the same methods described in Chapter 4. However, once it became apparent that there was discrepancies in the drainage areas reported by CRWR and those established by USGS, changes in methodology were made. The following sections provide an analysis of the problems encountered, the changes that were made, and the effect that these changes had on the final results.

5.2 RESULTS FROM FIRST RUN

As stated, the files needed for the Nueces basin were generated using the same methodology outlined in Chapter 4. Figure 5.1 shows the critical geographic themes in the project: control points, stream network and DEM.

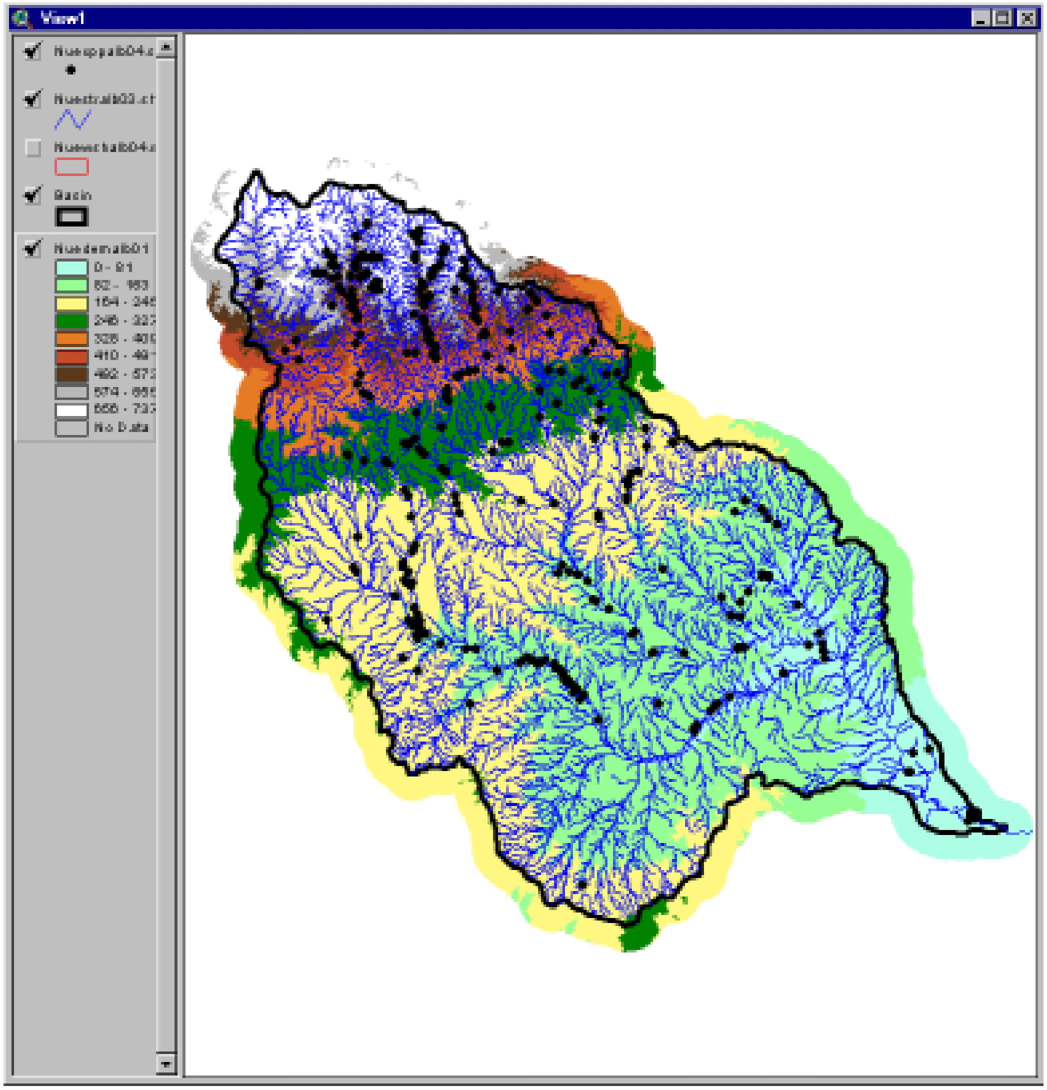

Figure 5.1: Nueces basin layout

There were 517 control points for which parameters were needed. Of these, 22 were USGS gage locations, 13 were contractor identified known flow locations (mainly points along the Edwards aquifer recharge zone), 13 were stream confluence locations (used for channel loss calculations), and the remaining 469 were water right/diversion locations. HDR specified the placement of the USGS, known flow, and confluence locations. For each point, a scanned topographic map was sent to CRWR to ensure proper placement. The water right/diversion points were checked and edited by TNRCC, and then returned to CRWR. All the points were then merged into one file.

The stream network was edited under normal procedures using the DRG as a reference. The main problem encountered with the Nueces was the existence of many braided stream segments. Each section of this nature had to be checked thoroughly in order to define one, clean drainage path. Another problem encountered was the existence of several streams in the RF3 file that crossed the established basin boundary. These extraneous segments had to be located and deleted in order to prevent the inclusion of areas not within the basin.

The DEM was built using 90m data (1:250,000) from the USGS website. The files were downloaded in 1 degree by 1 degree blocks, merged together, clipped to the basin, and then buffered 10km. Once completed, the DEM was processed, along with the final stream network, using the CRWR-PrePro extension. The required flow length grid was easily generated from the processed flow direction grid using the Hydrology extension in Arcview. This extension creates a grid with the length of flow from each cell to the outlet of the basin.

After placing all the points on the proper flow accumulation cell, the values of flow accumulation and flow length were reported and the watersheds were delineated. Upon checking the values of the USGS gages and known flow locations, it was clear that some errors did exist. Table 5.1 presents a comparison of CRWR reported values and USGS/HDR values.

Point	CRWR	USGS	HDR	Difference	Error
ID	mi^2	mi^2		mi^2	%
1	757.34	737		20	2.76
2	687.56	694		-6	-0.93
3	1863.73	1861		3	0.15
4	4158.02	4082		76	1.86
5	5307.64	5171		137	2.64
6	8284.85	8093		192	2.37
7	393.95	389		5	1.27
8	124.32	126		-2	-1.33
9	638.16	631		7	1.13
10	33.94		36	-2	-5.72
11	31.77		32	0	-0.72
12	209.68	206		4	1.79
13	248.03	241		7	2.92
14	18.02		18	0	0.11
15	4.37		6	-2	-27.17
16	45.48	45		0	1.07
17	165.23	168		-3	-1.65
18	97.59	96		2	1.66
19	153.39	149		4	2.95
20	12.00		12	0	0.00
21	57.57		55	3	4.67
22	104.93		105	0	-0.07
23	47.21		47	0	0.45
24	138.99	Spring		N/A	N/A
25	3431.05	3429		2	0.06
26	784.33	783		1	0.17
27	5480.88	5490		-9	-0.17
28	1158.43	1171		-13	-1.07
29	15628.00	15427		201	1.30
30	16722.87	16660		63	0.38
31	16986.07	16920		66	0.39

Table 5.1: Comparison of CRWR reported values and established drainage areas.

In general, most of the CRWR values were within an acceptable range of the USGS drainage areas. However, the highlighted records denote points that had significant errors in either relative difference or relative percent error from established values.

The errors in control point CP10 and CP15 stand out due to the percent error. As shown, the established drainage areas for these two points are 36 and 6 square miles, respectively. Due to such a small size, any difference in area results in a large percent error. The placement of these points was established by HDR and CRWR was instructed to adjust the location of these points up or down the stream until the drainage area matched the value that HDR had previously established. Therefore, these two points were moved downstream on the tributary to a location just above the junction of its connecting stream. Moving the points any further resulted in a large jump in drainage area. So, the values reported in the table represent the closest values obtained by CRWR. The small error of 2 square miles for each represents a limitation of the 90-meter data to accurately capture the drainage features of small watersheds.

Although the percent errors of points 4, 5, 6, 29, 30, 31 were relatively low (roughly 2% or less), Table 5.1 shows a significant discrepancy in total drainage area as compared to USGS values. All the points were located along the main stem of the Nueces River, with CP4 near the upper end and CP31 near the outlet. Moving downstream from CP4, the error in drainage area continued to increase. Therefore, it can be shown that a majority of the discrepancy (approximately 75 square miles) was found in the watershed of CP4, and that error was carried downstream through the remaining points. However, not only was the error being transferred, but additional area was also being added. By the time it reached CP29, the error had risen to 200 square miles.

On the whole, the majority of major errors in drainage area were positive, meaning CRWR was reporting values higher than that of USGS. Had some of the errors been negative, an assumption could have been made that one gage was taking area from another. However, the fact that CRWR was reporting a continuously higher drainage area means that additional area was being captured from outside the basin. Therefore, the first place to look for corrections was the area around the basin boundary.

From a comparison of the watershed file and the established basin boundary, it was found that the CRWR delineated basin boundary fell outside the established basin boundary. The discrepancies were particularly noticeable in areas with low relief, such as the western portion of the Nueces and the area near the coast. This error can also be attributed to deficiencies in the 90-meter data to accurately reflect small changes in the flat terrain. At this point in the research, however, data of higher resolution (such as 30-meter data) was not available. A diagram showing the errors in the CRWR delineation is shown in Figure 5.2.

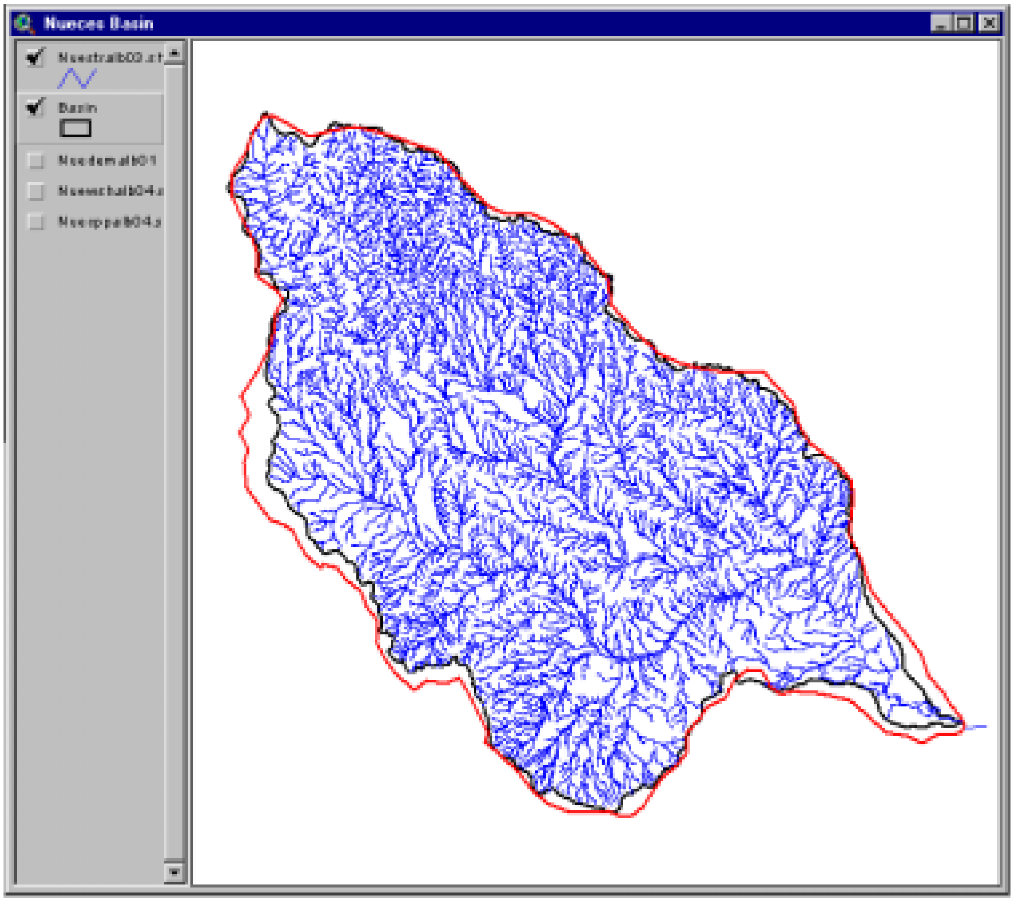

Figure 5.2: CRWR boundary (red) overlain on established boundary (black)

5.3 CHANGE IN METHODOLOGY

Without a DEM of higher resolution, a change in methodology had to be devised in order to prevent the additional capture in drainage area. One option was to build an artificial wall in the DEM by raising the cells along the existing basin boundary by an arbitrary amount. However, this method would serve to falsify the solution of the watershed delineator rather than using its capability to read the terrain.

Therefore, the solution settled upon was to burn additional streams into the basin buffer. The RF3 files from the basins surrounding the Nueces were merged, clipped to the basin buffer, and burned into the DEM along with those of the Nueces basin. The newly burned in streams would carry water away from the basin boundary from both sides, thus providing a more accurate depiction of the landscape. Figure 5.3 shows the close agreement between the new watershed delineation and the established basin boundary.

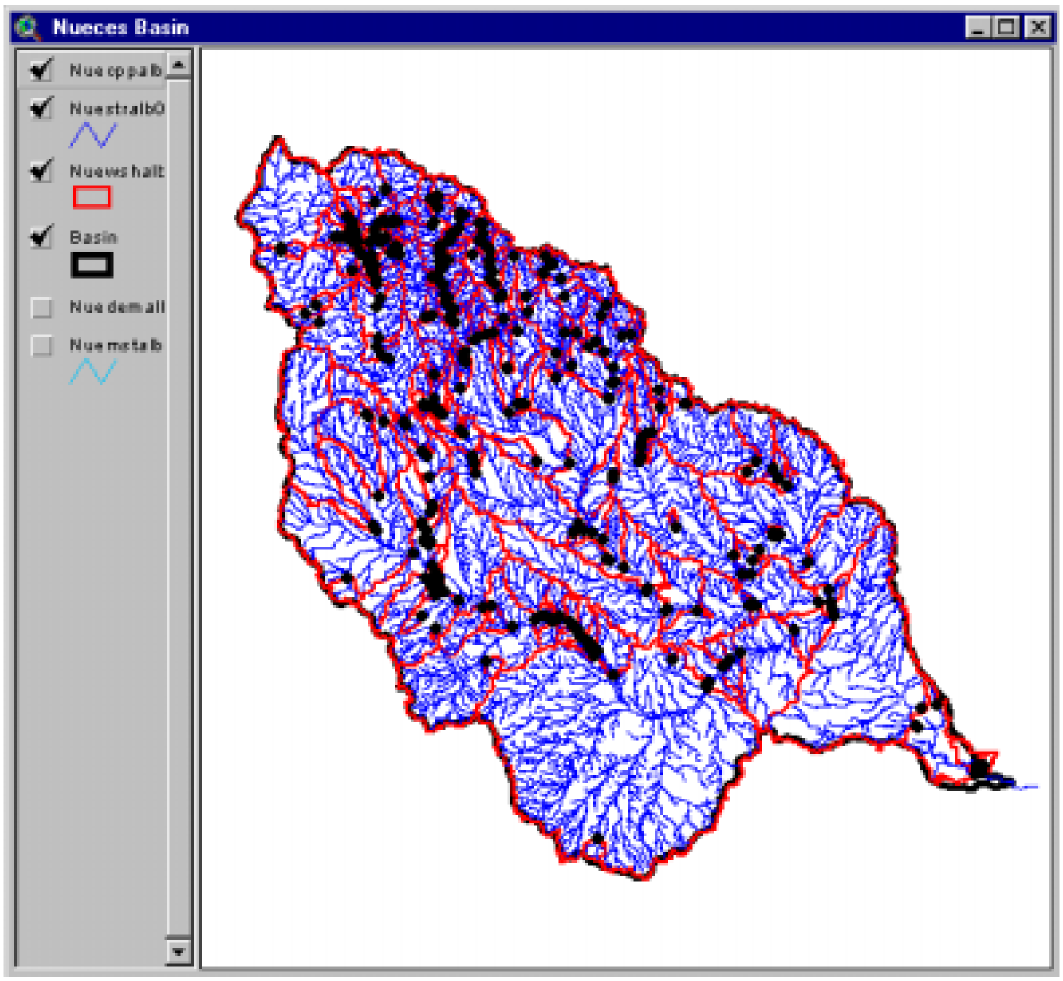

Figure 5.3: New watershed delineation overlain on basin boundary

5.4 Results from Second Run

The addition of the streams within the buffer had an obvious effect on the overall watershed delineations. Figure 5.3 showed how closely the watersheds matched the basin boundary, even in the flat, problematic areas from the first run. The following table (5.2) shows the drainage area results from the second run.

Control	CRWR (mi^2)		Difference (mi^2)		Error %	
Point	Version		Version		Version	
ID	2	1	2	1	2	1
1	757.35	757.34	20	20	2.76	2.76
2	687.10	687.56	-7	-6	-0.99	-0.93
3	1863.16	1863.73	2	3	0.12	0.15
4	4045.47	4158.02	-37	76	-0.89	1.86
5	5193.11	5307.64	22	137	0.43	2.64
6	8144.20	8284.85	51	192	0.63	2.37
7	393.18	393.95	4	5	1.07	1.27
8	124.32	124.32	-2	-2	-1.33	-1.33
9	637.42	638.16	6	7	1.02	1.13
10	33.96	33.94	-2	-2	-5.67	-5.72
11	31.77	31.77	0	0	-0.72	-0.72
12	208.49	209.68	2	4	1.21	1.79
13	246.82	248.03	6	7	2.41	2.92
14	18.03	18.02	0	0	0.17	0.11
15	4.39	4.37	-2	-2	-26.83	-27.17
16	45.19	45.48	0	0	0.42	1.07
17	165.23	165.23	-3	-3	-1.65	-1.65
18	97.42	97.59	1	2	1.48	1.66
19	153.20	153.39	4	4	2.82	2.95
20	12.00	12.00	0	0	0.00	0.00
21	57.46	57.57	2	3	4.47	4.67
22	105.08	104.93	0	0	0.08	-0.07
23	46.88	47.21	0	0	-0.26	0.45
24	138.99	138.99	N/A	N/A	N/A	N/A
25	3428.13	3431.05	-1	2	-0.03	0.06
26	784.26	784.33	1	1	0.16	0.17
27	5478.07	5480.88	-12	-9	-0.22	-0.17
28	1148.67	1158.43	-22	-13	-1.91	-1.07
29	15460.55	15628.00	34	201	0.22	1.30
30	16542.09	16722.87	-118	63	-0.71	0.38
31	16720.74	16986.07	-199	66	-1.18	0.39

Table 5.2: Comparison of drainage areas from first and second runs.

As shown, the errors in CP4, 5, 6, and 29 were significantly reduced in both percentage and total difference by simply adding streams to the buffer. This confirmed the assumption that the reason for the errors was due to the capture of area from outside the Nueces basin. However, the change in methodology actually produced worse result for points CP30 and CP31. In fact, instead of the overestimation that was found after the first run, the values for CP30 and CP31 in the second run were significantly lower than the USGS values.

Again, the drainage boundaries from the watershed file were compared with that of the established basin boundary. As shown previously in Figure 5.3, the boundaries matched almost perfectly for most of the basin. However, near the coast, there was still a bit of deviation, as shown in Figure 5.4.

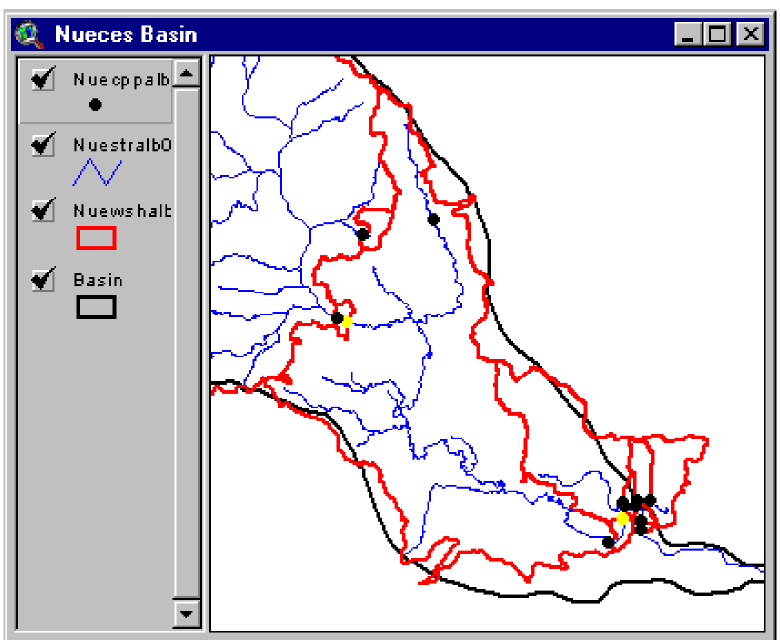

Figure 5.4: Lower portion of Nueces basin with CP30 (left) and CP31 (right) highlighted.

It can be seen from Figure 5.4 that the new watershed boundary does fall slightly inside of the established boundary. However, the difference does not seem to account for the almost 200 square mile difference shown for CP31 in Table 5.2. Therefore, it was then necessary to look at the incremental differences between the points at the lower end of the basin, specifically CP29, CP30, and CP31. Table 5.3 shows the incremental areas between the points.

Point ID	CRWR mi^2	USGS mi^2	Incremental CRWR	Difference USGS
29	15461	15427		
30	16542	16660	1081	1233
31	16721	16920	179	260

Table 5.3: Nueces Basin incremental areas.

Immediately, a 150 square mile difference was revealed in the incremental area between CP29 and CP30. Upon investigation of the watershed between the two points, there were not any significant discrepancies that would account for such a difference. HDR investigated old USGS records and found that the drainage area for CP30 had been copied errantly back in 1940 and the error had gone unnoticed until now. Once corrected, the CRWR areas more closely matched the new USGS numbers and were acceptable to the basin contractor.

5.5 Unresolved Errors

Although the addition of streams into the basin buffer eliminated the problems in the large watersheds that coincide with the basin boundary, the change did nothing to remedy problems in small watersheds and the middle portion of the basin. Through the quality control procedures, incidents of short-circuiting and incorrectly delineated watersheds below the 1000 cell flow accumulation threshold were found.

5.5.1 Short-Circuiting

Short-circuiting of the river network occurs when the flow direction grid and subsequent flow accumulation grid do not match the original stream network, as shown in Figure 5.5.

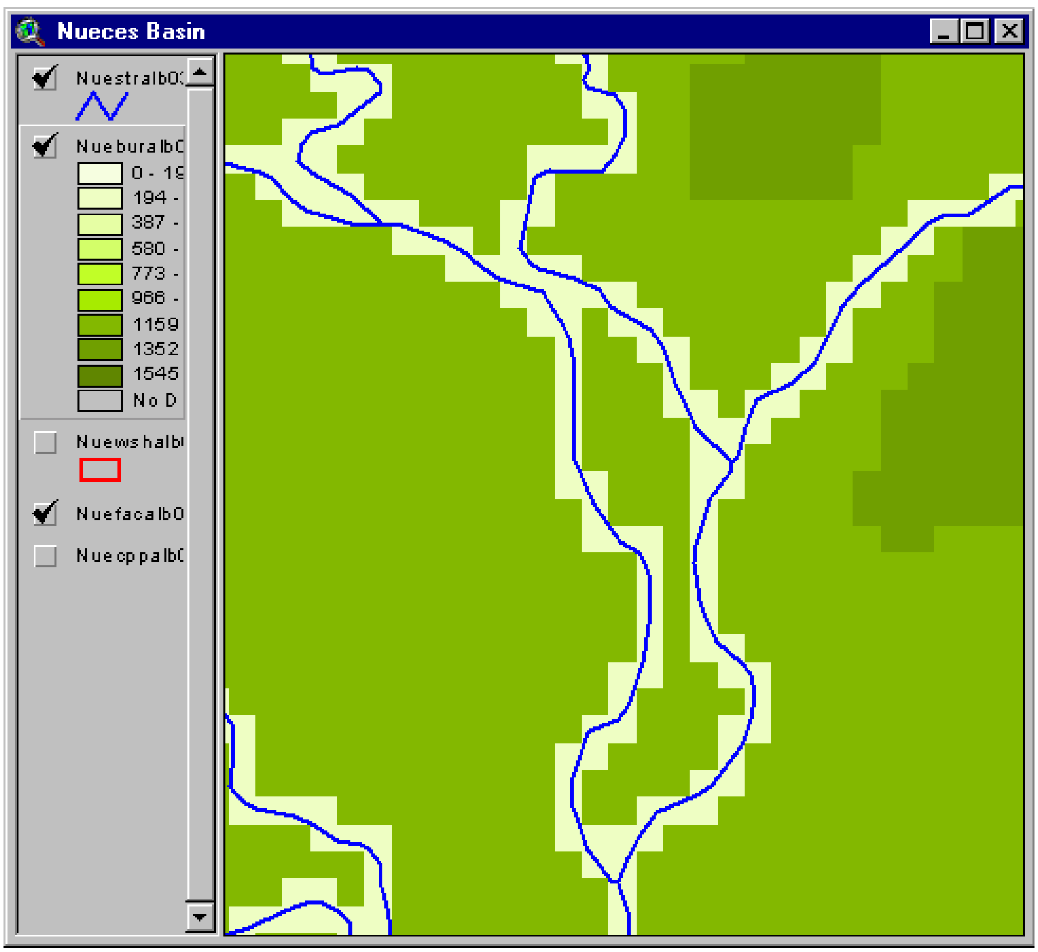

Figure 5.5: Stream network overlain on burned DEM.

This problem of short-circuiting usually occurs when using files of vastly different scales, as stated by Saunders (1999). From the figure, it is clear that the network should remain as two separate channels until the junction at the bottom of the frame. However, the burned channel shows a junction prematurely when the two stream channels get within one cell of each other. Later in the processing, only one of the channels will be chosen when creating the flow direction grid, thus causing an error in the flow accumulation of the other channel. Fortunately, in this section of the basin, there are no control points. However, short-circuiting becomes problematic when points are located along either section of the stream between the short circuit and the true junction. In that case, the drainage area of the control point has to be adjusted to arrive at the true value.

One solution to this problem is to manually adjust streams that appear to be too close during the original RF3 editing process. However, moving the streams could also adjust other features in the drainage scheme and is not recommended. The only real solution was to use higher resolution DEMs whose cells would be able to more closely represent the stream network. At this point in the research, without higher resolution grids, the basin had to be checked thoroughly by hand to correct for any short-circuiting.

5.5.2 Quality Control Watersheds

As stated in Chapter 4, a second element of the quality control procedure was to check all watersheds below a flow accumulation value of 1000 cells (approximately 3 square miles). Through other research projects at CRWR, the value of 1000 cells has been found to be a good starting threshold for quality control work when using 90-meter data.

After performing a query on the control point file, 68 points of the 517 points in the basin had a flow accumulation value of less than 1000. Immediately, 15 of those points were eliminated since they were either off-channel reservoirs or points that had already been corrected due to short-circuiting errors. Each of the remaining 57 control point watersheds were checked visually against the DRG maps to determine whether the delineations were performed accurately. If errors were found, a new watershed was delineated by hand, as shown in Figure 5.6.

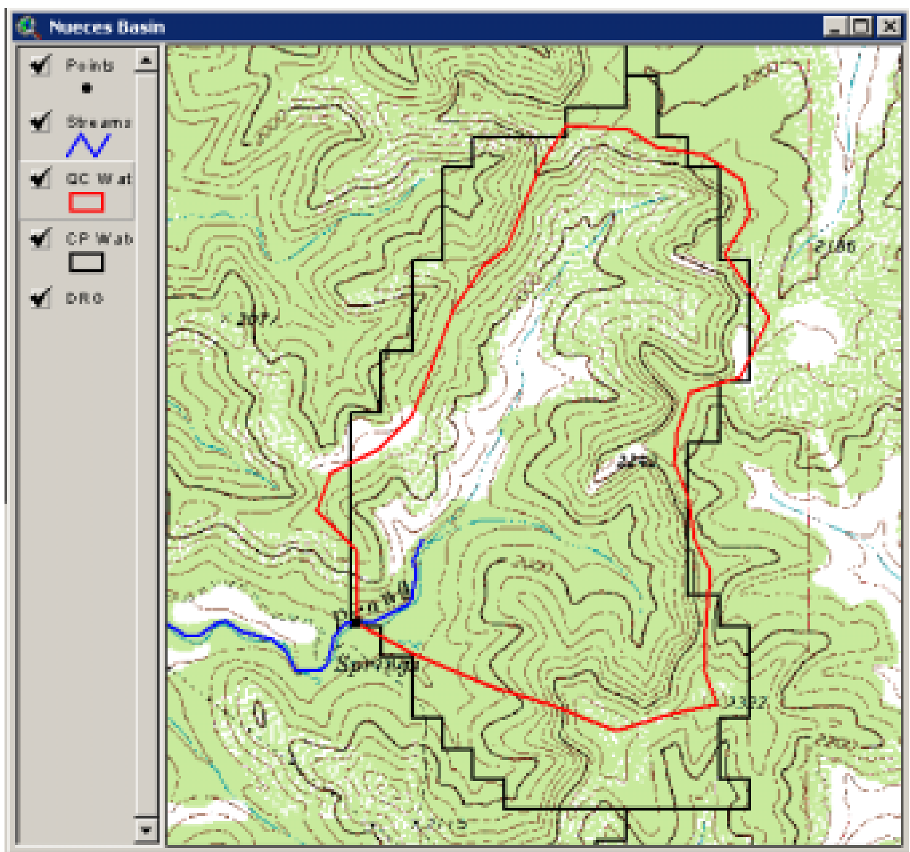

Figure 5.6: Hand-delineated watershed for quality control

The original watershed had an area of 0.68 square miles while the newly delineated watershed had an area of 0.51 square miles. As shown, the newly delineated watershed more closely fits the drainage features of the terrain. Of the 57 points checked, 11 were properly delineated by CRWR-PrePro, while the remaining 46 had to be delineated in the same manner as shown in Figure 5.6. Possible solutions to errors in the smaller watersheds are the use of higher resolution stream networks and DEMs.

5.6 CONCLUSION

In general, the results generated for the Nueces basin after adding the buffered streams were satisfactory. Almost all the values found by CRWR were within 2 percent of the known flow values defined by USGS and HDR. For a complete list of control points and parameters, see Appendix A.

After performing the quality control procedures, all instances of short-circuiting were found and corrected. Also, watersheds were delineated by hand for those sub-watersheds incorrectly defined by CRWR-PrePro, which mainly consisted of watersheds below the 1000 cell threshold.

Upon completion of the Nueces basin, it was suspected that most of the problems encountered could be eliminated by using higher resolution DEMs that more closely fit the terrain and scale of the stream network. The new 30-meter datasets became available just after the conclusion of work on the Nueces basin and were used for the remainder of the research. Results obtained from the new dataset are found in Chapters 6 and 7.

CHAPTER 6: CASE STUDY – GUADALUPE & SAN ANTONIO BASINS

6.1 INTRODUCTION

The Guadalupe and San Antonio river basins are also located in South Texas, adjacent to the Nueces basin (refer to map in Chapter 1). In fact, the San Antonio runs along the eastern edge of the Nueces basin, while the Guadalupe runs along the eastern edge of the San Antonio basin. Near the coast, the San Antonio joins the Guadalupe before exiting into the Gulf. At that point, the total area of the two basins is 10,125 square miles, with 5954 square miles contributed by the Guadalupe and 4171 square miles contributed by the San Antonio. Again, the basin contractor for these two basins was HDR, Inc. Since the San Antonio flows into the Guadalupe, HDR modeled the two basins as one unit. However, for the purposes of this research, each basin was processed separately.

As with the Nueces, average precipitation and curve number parameters were replaced by the flow length parameter for both basins. The basins were first processed using the procedure described in Chapter 4. However, through experience with the Nueces and the recent availability of 30-meter data, changes in the methodology were made and the basins were entirely reprocessed. The following chapter discusses the results obtained from the use of 90-meter data, the changes made to accommodate the 30-meter data, and the final results calculated from the new datasets.

6.2 RESULTS FROM FIRST RUN

As stated, each basin was first processed using the original procedure outlined in Chapter 4. The critical files for each basin are shown in Figures 6.1 and 6.2. These files include the 90-meter DEM, the single-line stream network, and the basin control points.

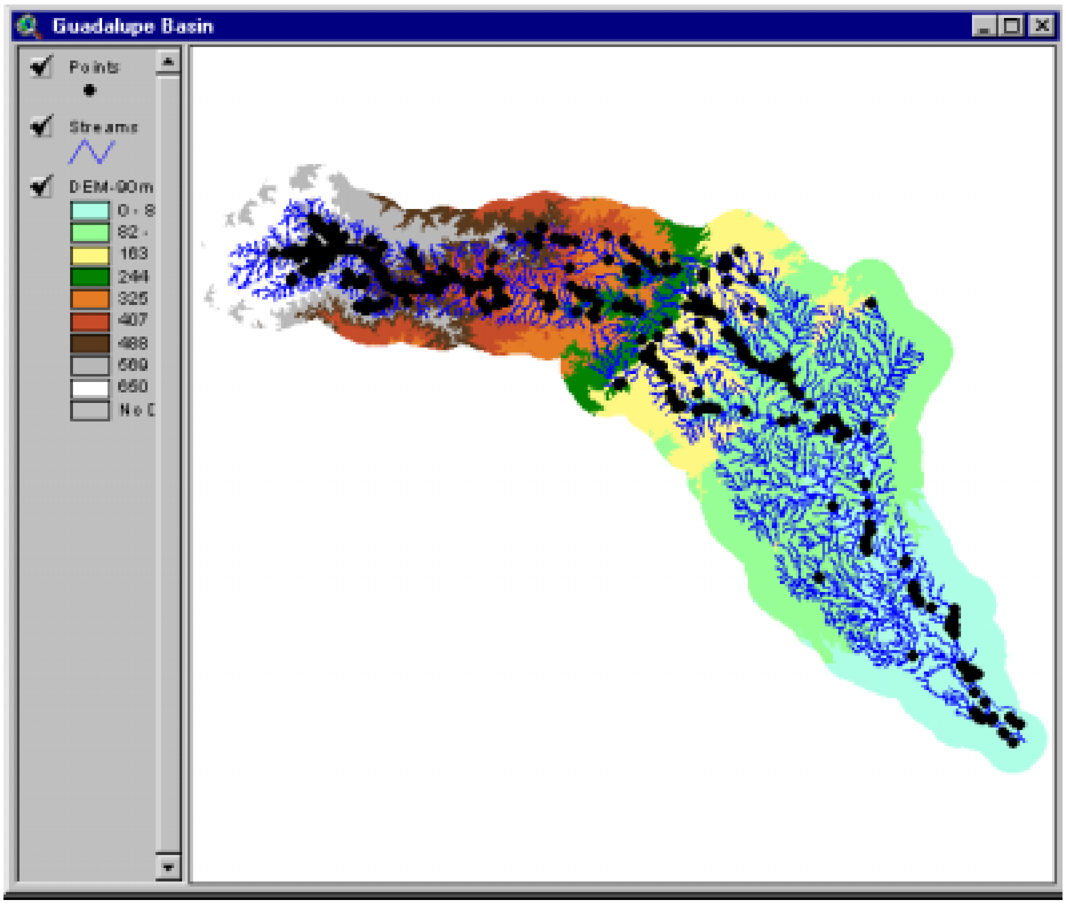

Figure 6.1: Layout of Guadalupe River basin

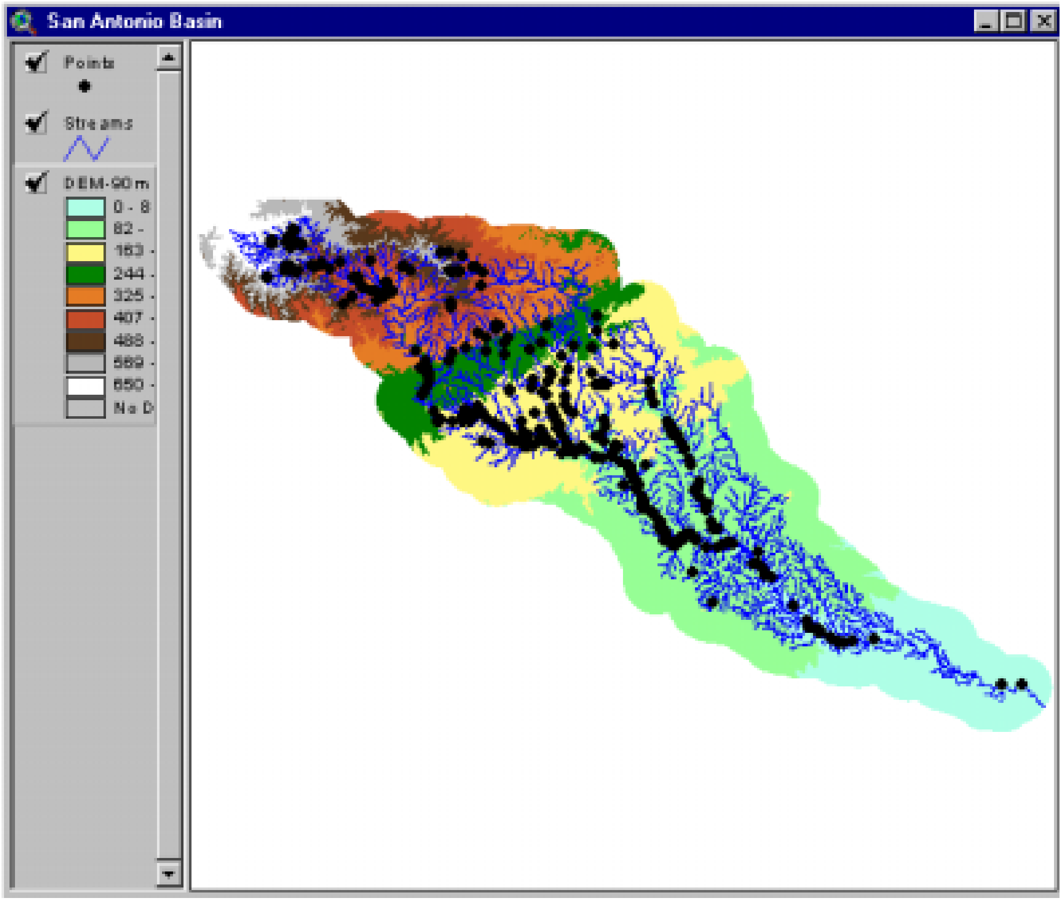

Figure 6.2: Layout of San Antonio River basin

There were a total of approximately 1300 control points (800 and 500 for the Guadalupe and San Antonio basins, respectively) for which parameters were needed. Of these 1300 points, 30 were USGS gage locations, 10 were contractor identified known flow locations, 40 were stream confluence locations, and the remaining 1220 were water right/diversion locations. Again, all known flow and confluence points were placed by HDR, while TNRCC located the water right/diversion points. Once completed, all points were sent to CRWR and merged into one master file for each basin.

The stream network editing process went much more smoothly with the Guadalupe and San Antonio basins due to the lack of braided streams. Also, TNRCC provided stream edits with the water right files that were merged into the existing network. This saved CRWR time in manually checking each of the points for placement on existing streams. Also, another improvement from the Nueces editing process was the existence of the USGS centerline file. Instead of manually digitizing streams in place of the deleted open-water features, the USGS NHD centerlines were merged into the existing network to fill any gaps.

The 90-meter data was processed in the same manner as the first run of the Nueces. The grids for each basin were downloaded, merged, clipped, and buffered. The DEMs and stream networks were then processed separately using CRWR-PrePro. Also, the flow length grid was generated using the Hydrology extension in Arcview.

Without the tools created later to automate the point placement process, each of the 1300 points had to be placed and checked manually to ensure proper location on the flow accumulation grid. For such a large coverage, this process proved to be very long and tedious, requiring the work of several researchers over the span of a week. Once all the points were placed, the values of flow accumulation and flow length were reported and the incremental watersheds for each point were delineated. Since this process had previously been performed on the Nueces, errors were anticipated. The following sections detail the errors found in the Guadalupe and San Antonio, respectively.

6.2.1 Guadalupe Results

With all the parameters generated, the first step was to check the accuracy of the USGS gage locations and the HDR known flow locations. Table 6.1 presents a comparison of these known flow locations and the CRWR reported values.

Point	CRWR	USGS	HDR	Difference	Error
ID	mi^2	mi^2		mi^2	%
1	870.83	839		32	3.79
2	1353.13	1315		38	2.90
3	1471.73	1432		40	2.77
4	1560.92	1518		43	2.83
5	136.37	130		6	4.90
6	2103.38		2103	0	0.02
7	94.13		94	0	0.14
8	359.75	355		5	1.34
9	417.92	412		6	1.44
10	848.1	838		10	1.21
11	323.07	309		14	4.55
12	480.15	460		20	4.38
13	593.68	549		45	8.14
14	5078.28	4934		144	2.92
15	5419.05	5198		221	4.25
16	519.48	494		25	5.16
38	N/A	10128		N/A	N/A

Table 6.1: Comparison of CRWR reported values and established drainage areas

Clearly, it can be seen that the results from the first run of the Guadalupe were not satisfactory. The highlighted control points show locations with a relative area of greater than 3%, which includes half of the USGS gage locations. Also, the table shows that the remaining errors for the gages were between 1.5%

and 3%. Another thing to note is that every CRWR value was higher than either the USGS or HDR known drainage area. This fact signifies a specific problem of drainage area being captured from outside the established basin boundary. The reason for higher errors than the Nueces across the board is due to the relative size of the two basins. Since the Guadalupe basin is much smaller, any errors in drainage area are magnified.

When inputted into the water availability model, the USGS gages are used to calculate the flows at all other points in the basin through a drainage area ratio. Therefore, there is no reason to study the accuracy of the remaining control points within the Guadalupe until the errors in the gages are corrected. Therefore, further study of the Guadalupe can be found in section 6.4 of this chapter.

6.2.2 San Antonio Results

With the Guadalupe, San Antonio and Nueces all in such close proximity to each other, the same types of errors were expected in the results of the San Antonio as were found in the others. However, the fact that each of the basins were being processed almost simultaneously due to project deadlines meant that the first run of the San Antonio was also performed using the original procedures outlined in Chapter 4. Surprisingly, the results from the first run were quite promising, as shown in Table 6.2.

Point ID	CRWR mi²	USGS	HDR	Difference mi²	Error %
		mi²			
17	7.75		8.3	-1	-6.63
18	46.79	41.8		5	11.94
19	140.36	137		3	2.45
20	191.56	189		3	1.35
21	639.42	634		5	0.85
22	15.00		15.6	-1	N/A
23	655.00		650	5	0.77
24	9.89		13.1	-3	-24.50
25	57.96		58.3	0	-0.58
26	99.74		99.7	0	0.04
27	975.54	967		9	0.88
28	1326.63	1317		10	0.73
29	1782.49	1743		39	2.27
30	7.97		9.4	-1	-15.21
31	65.43		65.4	0	0.05
32	2137.81	2113		25	1.17
33	68.17	68.4		0	-0.34
34	271.01	274		-3	-1.09
35	824.98	827		-2	-0.24
36	257.95	239		19	7.93
37	3972.22	3921		51	1.31

Table 6.2: Comparison of CRWR reported values and established drainage areas.

In general, the CRWR reported values closely matched that of the USGS and HDR. The highlighted records show 6 points that have particularly high errors in relative percent and/or difference. However, 3 of these 6 points are HDR established known flow locations, for which CRWR was instructed to fit the values as closely as possible (as referenced in section 5.2). The 12 percent error in CP18 was produced by only a 5 square mile difference in area, which can be considered negligible in such a study. The errors in CP36 and CP37 were the result of the same problems encountered in the Nueces and Guadalupe. The watershed of each point ventured outside the established basin boundary, capturing area from the adjacent basin.

The exact reason for such improved results in the first run of the San Antonio over the first runs of the other two basins was not known. The researchers at CRWR have noticed differences in the quality of the DEM and the density of the original RF3 network in varying locations. Or, it may simply be that experience gained in building the stream networks for the first two basins in the study led to an improved effort in building the network for the San Antonio basin. At any rate, it was clear that there was room for improvement in the methodology, particularly with respect to the scale of the DEMs being used in the processing. It was at this point in the research that a seamless, 30-meter DEM for the entire state of Texas was completed by USGS.

6.3 CHANGES IN METHODOLOGY

In addition to the incorporation of streams in the buffered area, the availability of the 30-meter dataset was a clear indicator of the next possible improvement in the methodology. Obviously, a more defined terrain would produce more accurate drainage areas across the basin, and could even eliminate errors in places of low relief. Also, the 30-meter (1:24,000 scale) DEM would more closely fit the 1:100,000 scale river network, thus eliminating many of the short-circuiting problems experienced with 90-meter data.

Some anticipated problems with using the 30-meter DEM were increased file size and processing time. For example, the file size of the Guadalupe DEM was only 3 MB at 90-meter resolution, but increased to 57 MB at 30-meter resolution. The reason for this drastic increase was the number of cells stored in the higher resolution grid. The 90-meter DEM for the Guadalupe contained 9 million cells, while the 30-meter DEM contained 80 million cells. Also, since CRWR-PrePro works on a cell-by-cell basis, the increase in cells resulted in an increase in processing time, as discussed in the next section..

Previous research at CRWR indicated that Arcview might have a problem performing calculations on such large grids. It was suggested that a cell threshold of approximately 40 million exists and, if exceeded, would cause the system to crash. Before trying other options, the threshold was put to test and the system did, in fact, crash during the initial processing of the DEM. Therefore, the alternatives were to process the DEM using Arc/Info, or divide the basin into smaller, manageable parts. The next two sections explain both of these alternatives.

6.3.1 Processing DEM using Arc/Info

Without the built in commands of the CRWR-PrePro extension, a new method had to be devised for performing the same tasks in Arc/Info. However, the stream network file first had to be converted to a grid in Arcview before being incorporated into Arc/Info. Also, the resulting grid had to contain values of one along the stream cells, and no data everywhere else. So, a new field was added to the stream network attribute table that contained a value of one for every arc in the shapefile. Then, during the conversion, Arcview asked for the column in the table to be used for the grid ID values. At this point, the newly created field was chosen.

Once the necessary stream grid was created, it was then taken into the Arc/Info format for further processing. First, the stream grid was multiplied by the DEM to produce a new stream grid with values of elevation along the streams, rather than values of 1. Next, an elevation increment of value greater than the highest peak in the DEM was added to the original DEM. This produced a new DEM that had simply been raised a certain height. Next, the new stream and DEM grids were joined using the *merge* command in Arc/Info. The result of the merged grids was the Burned DEM.

At this point, a prompt in Arc/Info stated that a value attribute table (VAT) has not been created for the Burned DEM. This prompt was an indication of the cell threshold spoken of earlier. Arc/Info automatically builds the VAT file for grids up to a certain size and prompts the user to build one if the grid is too large. However, Arcview simply crashes if the grid is too large. Therefore, before continuing, a VAT file for the Burned DEM was built using the *buildvat* command in Arc/Info.

The next step in the process was the creation of the FILL, FDR, FACC grids. Commands in Arc/Info already existed to perform these tasks. The *fill* command used the Burned DEM as an input to create the Filled DEM. During this process, the FDR was created automatically. Finally, the *flowaccumulation* function used the FDR grid to create a flow accumulation grid (FACC).

One advantage of processing the grids in Arc/Info is that the system allows the user to input all the necessary functions in the form of a text file. This way, a batch process can be set up so that the user does not need to input each command as the previous one is completed. Below are the commands used in the grid processing.

Grid: **setcell DEM**
Grid: **setwindow DEM**
Grid: **DEMSTREAM = STRMGRID * DEM**
Grid: **DEMPLUS = DEM + 10000**
Grid: **BURNDEM = merge (DEMSTREAM, DEMPLUS)**
Grid: **buildvat BURNDEM**
Grid: **fill BURNDEM FILLDEM # # FDR**
Grid: **FACC = flowaccumulation (FDR)**

Once the flow accumulation grid was created, the control points were relocated to the proper flow accumulation cell in the Arcview format. Then, in the same manner as the stream network, the control points were converted to a grid using the control point ID numbers as the values for the new grid cells. Next, back in Arc/Info, the control point grid and FDR grid were used as inputs into the *watershed* function to create the watershed delineations, as shown by the following command.

Grid: **WTRSHEDS = watershed (FDR, CPGRID)**

The first few attempts at grid processing using Arc/Info resulted in error messages. During the *fill* process, several large, temporary grids were created that filled the entire hard-drive of the computer. However, once enough space was cleared to accommodate the *fill* step, the rest of the processing went smoothly. As anticipated, the processing time required for the 30-meter grids was quite long. The run-time to complete the burn, fill, flow direction, and flow accumulation steps for the Guadalupe was approximately 15 hours. The same task for the 90-meter data was completed in approximately 1 hour.

6.3.2 Sub-dividing the Basin DEM

For both the Guadalupe and San Antonio basins, the grid processing was completed without having to divide the basins into smaller parts. However, after the first few failed attempts due to lack of space on the hard-drive, a method for sub-dividing the basins into smaller parts was devised. Although, in the end, the method was not utilized for the San Antonio and Guadalupe, the method could be used for processing the larger basins in Texas (namely, the Trinity, Brazos, and Colorado). Therefore, the methodology to complete the sub-division was included in this case study.

The first step was to decide upon an appropriate amount of sub-divisions for the basin. It is recommended to divide the basin into parts of no greater than 15-20 million cells for processing efficiency. Polygons built from a combination of 8-digit HUCs were used. With the polygons chosen, points had to be placed on the stream network at the outlet of each polygon. These locations would then be converted to grids for use in later stages of the processing. The generated polygons were then used to clip and buffer the DEM. The sub-sections of the DEM were then processed using CRWR-PrePro in Arcview or the commands described previously for Arc/Info.

The main challenge of this process was to be able to transfer the flow accumulation from an upstream sub-basin to the next sub-basin downstream. This task was also complicated by the presence of the basin buffer for each of the subbasins. The commands used to accomplish this task and descriptions of each command will follow. Also, Figure 6.3 can be used as a visual reference,

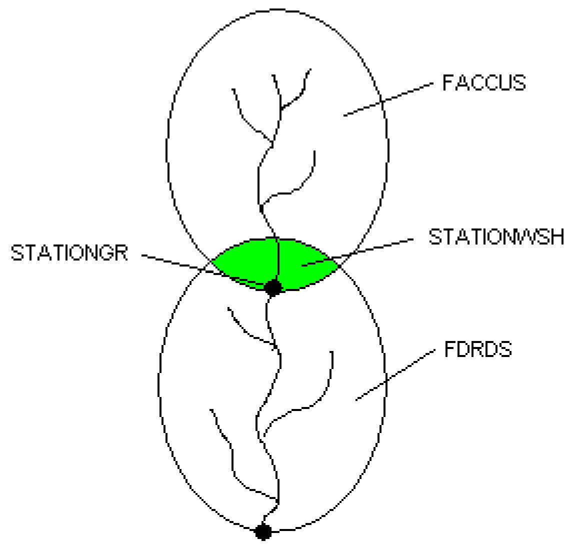

Figure 6.3: Diagram of sub-division process

where: STATIONGR = Control point at basin boundary
FACCUS = Upstream flow accumulation grid
FDRDS = Downstream flow direction grid
STATIONWSH = Watershed above STATIONGR using FDRDS

Since the two basin buffers overlap, the conjoined area between the two must be eliminated to prevent double counting the area. So, the first step was to generate a watershed above the control point that was placed at the basin boundary previously. The following command accomplished this step.

Grid: **STATIONWSH = watershed (FDRDS, STATIONGR)**

Notice the watershed was generated from the downstream basin only. This ensured that the watershed extended only from the control point to the upper end of the downstream basin.

The next step was to create a weight grid that would only include the upstream flow accumulation at the control point, and values of zero for all other cells within the STATIONWSH. A grid with values of zero at every cell was created with the following command.

Grid: **WEIGHT0 = con (STATIONWSH > 0, 0)**

To create a grid with only the value of the upstream flow accumulation at the control point location, the control point grid was first divided by itself, producing a grid with a value of one at the control point location and no data everywhere else. This grid was then multiplied by the upstream flow accumulation grid to produce the desired grid.

Grid: **WEIGHTST = (STATIONGR/STATIONGR)*FACCUS**

Finally, the two weight grids just created were merged to form the grid with upstream flow accumulation and zeros elsewhere.

Grid: **WEIGHT = merge (WEIGHTST, WEIGHT0)**

A few more steps remained in the transfer of upstream flow accumulation to the downstream basin. The next goal was to create a grid the same size and shape as the downstream basin with values of 1 everywhere except the location of the control point (where the value of upstream flow accumulation would be located). This “total weight” grid could then be used to calculate a new flow accumulation grid for the downstream basin. Step one in this process was to create the mask grid that contained a value of one at every cell in the downstream basin. This task was performed by dividing the downstream flow direction grid by itself.

Grid: **MASK = FDRDS/FDRDS**

With the mask created, the total weight grid was generated by merging the MASK grid with the WEIGHT grid generated above.

Grid: **TOTALWEIGHT = merge (WEIGHT, MASK)**

Finally, the new downstream flow accumulation grid that included the flow accumulation from the upstream area was computed by running the flow accumulation function on the TOTALWEIGHT grid.

Grid: **FACCDS =flowaccumulation(FDRDS,TOTALWEIGHT)**

This process not only works for merging one upstream basin to one downstream basin, but it can also be applied to situations where two or more upstream basins are flowing into one downstream basin. To accomplish this task, the first 4 steps are run on each of the upstream basins. Once completed, all WEIGHT grids for the upstream basins must be merged together with the MASK grid before calculating the downstream flow accumulation grid.

6.4 RESULTS FROM SECOND RUN

Although the processing time increased more than 10-fold, the incorporation of 30-meter resolution DEMs was a vital step in producing accurate drainage areas for the control points in the Guadalupe and San Antonio basins. Clearly, the increased detail of the new dataset was able to more accurately represent the drainage features of the landscape, as shown in Figure 6.4.

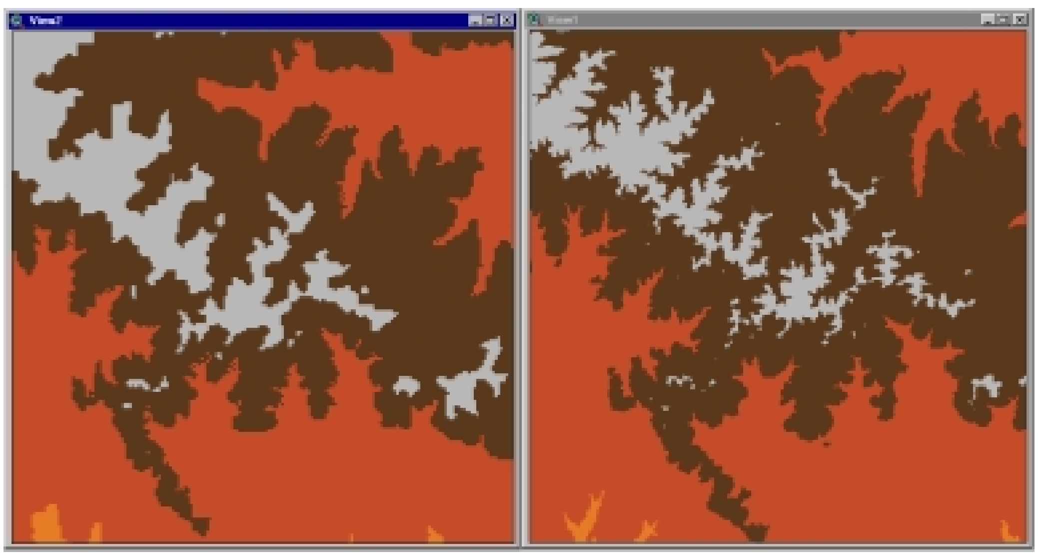

Figure 6.4: Comparison of 90m (left) and 30m(right) data images

Not only were the watersheds defined more precisely, but the fact that the 1:24,000 scale elevation data more closely fit the 1:100,000 scale stream network eliminated most instances of short-circuiting in the basin. Also, the DEM, along with the buffered streams, eliminated the problem of drainage area being captured from outside the basin. Sections 6.41 and 6.42 detail the results of the Guadalupe and San Antonio basin parameters, respectively.

6.4.1 Guadalupe Results

After generating the drainage areas for each of the control points in the Guadalupe basin, the results were astounding. Table 6.3 shows how closely the CRWR generated drainage areas matched the established USGS/HDR drainage areas in the second run, as compared to those values found in the first run.

Point	*Version 2*	*Version 1*	USGS	HDR	*Version 2*	*Version 1*
ID	Area (mi^2)		Area (mi^2)		% Error	
1	837.78	870.83	839		-0.15	3.79
2	1314.7	1353.13	1315		-0.02	2.90
3	1432.25	1471.73	1432		0.02	2.77
4	1519.03	1560.92	1518		0.07	2.83
5	129.54	136.37	130		-0.35	4.90
6	2103.07	2103.38		2103	0.00	0.02
7	93.85	94.13		94	-0.16	0.14
8	355.31	359.75	355		0.09	1.34
9	412.43	417.92	412		0.10	1.44
10	838.81	848.1	838		0.10	1.21
11	310.63	323.07	309		0.53	4.55
12	459.79	480.15	460		-0.05	4.38
13	549.05	593.68	549		0.01	8.14
14	4935	5078.28	4934		0.02	2.92
15	5195.88	5419.05	5198		-0.04	4.25
16	493.42	519.48	494		-0.12	5.16
38	10122	N/A	10128		-0.06	N/A

Table 6.3: Comparison of results from second run to established USGS/HDR values

The highlighted columns show the values found for the USGS/HDR known flow locations and the percent error between the two, respectively. Clearly, the results from the second run leave almost no room for improvement, at least at the large, watershed scale. All drainage areas for gaged locations were less than half a percent difference from their known values. In fact, not one of the drainage areas shown differed from its established value by more than a few square miles, even for watersheds as large as 5200 square miles. CP38 represents the drainage area at the confluence of the Guadalupe and San Antonio basins. At this point, the known drainage area is 10,128 square miles. CRWR reported an area of 10,122 square miles, a mere 6 square mile difference. Overall, the results for the USGS gage watersheds in the first run differed by an average of 3.15%. After incorporating the 30-meter data, the difference over the same set of watersheds was reduced to 0.11%.

6.4.2 San Antonio Results

The results from the second run on the San Antonio basin were nearly as impressive as the Guadalupe results. Table 6.4 details these results.

Point	Version 2	Version 1	USGS	HDR	Version 2	Version 1
ID	Area (mi^2)		Area (mi^2)		% Error	
17	8.19	7.75		8.3	-1.28	-6.63
18	44.11	46.79	41.8		5.53	11.94
19	136.04	140.36	137		-0.70	2.45
20	187.04	191.56	189		-1.04	1.35
21	633.63	639.42	634		-0.06	0.85
22	648.84	655.00		15.6	N/A	N/A
23	648.84	655.00		650	-0.18	0.77
24	11.65	9.89		13.1	-11.07	-24.50
25	58.27	57.96		58.3	-0.05	-0.58
26	99.60	99.74		99.7	-0.10	0.04
27	961.51	975.54	967		-0.57	0.88
28	1310.35	1326.63	1317		-0.50	0.73
29	1737.49	1782.49	1743		-0.32	2.27
30	9.41	7.97		9.4	0.14	-15.21
31	64.55	65.43		65.4	-1.31	0.05
32	2107.81	2137.81	2113		-0.25	1.17
33	68.32	68.17	68.4		-0.12	-0.34
34	273.97	271.01	274		-0.01	-1.09
35	825.42	824.98	827		-0.19	-0.24
36	239.26	257.95	239		0.11	7.93
37	3906.02	3972.22	3921		-0.38	1.31

Table 6.4: Comparison of results from second run to established drainage areas.

Again, almost every value found for a USGS gage location fell within a half of a percent of the established value. Even problematic points such as CP17, 18, 24,30, and 36 were drastically improved. In the first run, the average error across the USGS gaged watersheds was 4%. After the second run, this error was reduced to 1%, which is clearly sufficient when dealing with watersheds of this size.

6.5 Quality Control

Regardless of the accuracy found with respect to the USGS gage watersheds, the true test of the dataset was its ability to accurately delineate the smaller watersheds. Also, by proving the accuracy of both the large and small watersheds, an assumption can be made that all watersheds in between will also be relatively accurate. Therefore, the same quality control test described in Chapter 4 was also performed on the results of the Guadalupe and San Antonio.

When performing the quality control on the 90-meter data, all watersheds below a 1000 cell flow accumulation threshold were visually checked and manually re-delineated if problems were found. At 90-meter resolution, a 1000 cell flow accumulation corresponds to a drainage area of approximately 3 square miles, whereas the same number of cells corresponds to an area of approximately 0.3 square miles when using 30-meter data. It was first thought that an increase in the cell threshold was appropriate when moving to 30-meter data since the corresponding 1000 cell area was so small. However, with the success of the USGS gage delineations, it was decided that the original 1000 cell threshold might still hold true for the higher resolution data sets. To truly test the assumption, each watershed below 1000 cells was delineated manually from the DRG maps, instead of simply checking the watersheds visually. Table 6.5 is a synopsis of the results from both the Guadalupe and San Antonio basins.

CP ID	# of Cells	Area (mi^2)	QC Area (mi^2)
61902105302	0	0.00	0.16
11903944301	55	0.02	0.69
11805371201	118	0.04	0.03
11805107301	168	0.05	0.05
61802036301	168	0.05	0.05
61802036002	168	0.05	0.05
11805107002	168	0.05	0.05
11804539001	171	0.06	0.05
11804539301	171	0.06	0.05
11905423303	218	0.07	0.06
11905423301	233	0.07	0.06
61803825302	271	0.09	0.09
11905423304	336	0.11	0.10
11905423001	336	0.11	0.10
11904510303	349	0.11	0.09
61803838301	360	0.12	0.11
61801967301	398	0.13	0.12
11805371101	571	0.18	0.16
11905423302	590	0.19	0.18
61801975001	674	0.22	0.21
61801975301	674	0.22	0.21
61801954002	796	0.26	0.25
61801954302	803	0.26	0.25
61902168001	804	0.26	0.28
11904510301	874	0.28	0.25
61902168301	957	0.31	0.31

Table 6.5: Comparison of computer and hand-delineated watersheds

As shown, even for watersheds as small as five hundredths of a square mile, the 30-meter data was able to produce extremely accurate results. For the 26 watersheds delineated, only 2 differed by more than three hundredths of a square mile (see highlighted points). The reason for the discrepancy in both

CP61902105302 and CP11903944301 was an error in the stream network. Both points had been placed near the end of a stream that had not been digitized to the full extent of its reach. Otherwise, the watershed delineation would have been accurate. Therefore, as a result of this study, it was concluded that a simple visual check of the watershed below the 1000 cell threshold is sufficient to evaluate the quality of the results. Further analysis of the cell threshold issue can be found in Chapter 8.

6.6 CONCLUSION

In conclusion, the incorporation of the 30-meter DEM into the established methodology provided outstanding results. A complete list of result for each control point in the Guadalupe and San Antonio basins can be found in Appendix B and C, respectively. Nearly every value generated by CRWR matched USGS/HDR values within an error of less than a half of a percent. These results were shown to be significantly better than those obtained through the use of 90-meter data. Not only did the 30-meter data provide accurate results for the large, USGS watersheds, but the data also produced similar results for watersheds of a few hundredths of a square mile. The ability to delineate watersheds over such a wide range of areas (10,000 mi^2 – 0.05 mi^2) is certainly a powerful advance in water resource management.

The only drawbacks to the use of 30-meter data were the cumbersome file sizes and the significant increase in basin processing time. Functions that ran for 1-2 hours with 90-meter data lasted for approximately 15 hours with 30-meter data. The processing time is expected to increase significantly for larger basins, making it almost impossible to perform the processing on a basin-wide scale. However, a method for sub-dividing the basin into smaller, more manageable sections was developed that should alleviate some of the problems anticipated for larger basins.

CHAPTER 7: CASE STUDY – SAN JACINTO BASIN

7.1 INTRODUCTION

The final basin studied in this research was the San Jacinto basin. The basin is located in the southeastern portion of Texas and drains an area of approximately 4000 square miles, including the City of Houston. The basin contractor for the San Jacinto was Espey, Padden Consultants, Inc. Unlike the previous 3 basins, the basin contractor for the San Jacinto required the full set of parameters for each control point: drainage area, average curve number, average precipitation and the next downstream control point. Since Espey was using curve numbers and precipitation to distribute flows throughout the basin, the flow length parameter was not required.

Due to the success found from using the 30-meter data, the process for the San Jacinto was not run using 90-meter data. Therefore, instead of comparing results from 2 separate runs on the basin, the main goal of this study was to judge the ability of the 30-meter DEM to capture accurate drainage areas in a basin of rather low relief. Also, a secondary goal was to streamline steps in the methodology in order to compensate for the increase in processing time that result from the use of 30-meter data. Areas with room for improvement were the manual placement of control points on the stream network and the manual generation of a table locating the next downstream point. Figure 7.1 shows the critical files used in the basin processing: control points, stream network, and 30-meter DEM.

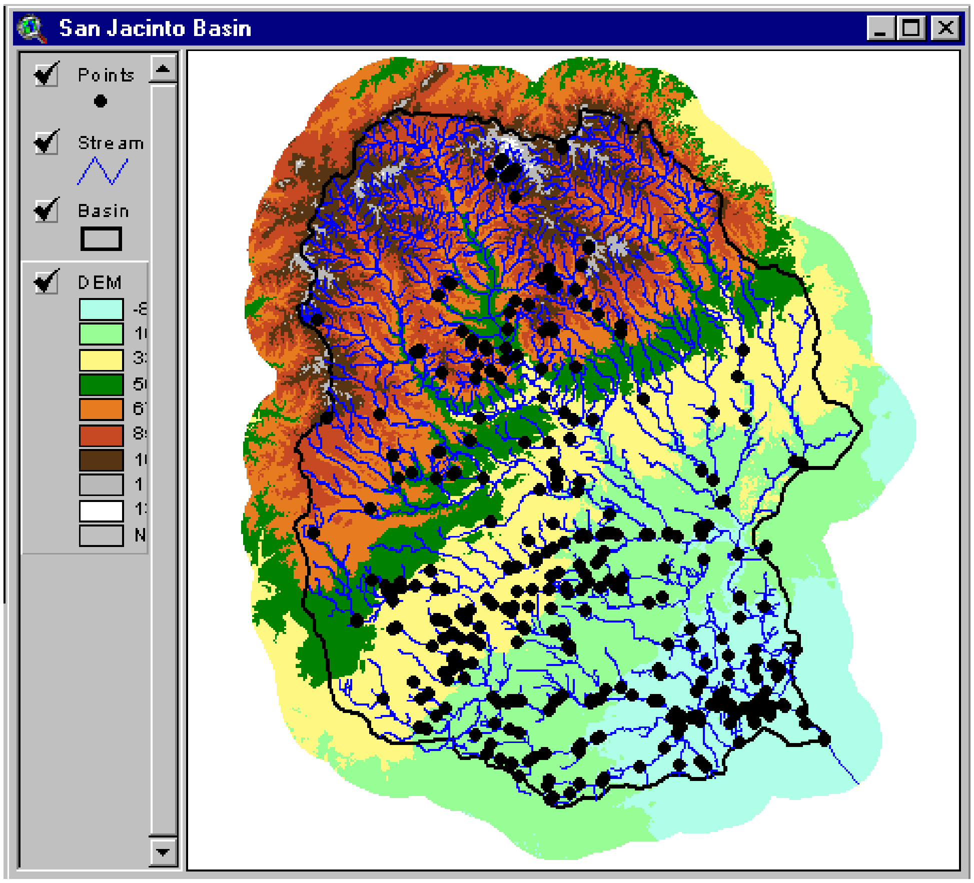

Figure 7.1: San Jacinto basin layout

7.2 Basin Processing

There were 426 control points for which parameters were needed. In addition to the 204 water right/diversion points and 19 stream gage locations, a few new point locations were incorporated into the basin study. Espey requested the inclusion of 187 specified return flow locations and 19 water quality segment endpoints. The return flow locations were delivered to CRWR as an Excel spreadsheet with latitude and longitude coordinates, from which a point coverage was created. The water quality segment endpoints were generated by TNRCC.

The stream network editing for the San Jacinto basin presented a different set of problems compared to the previous 3 basins studied. Instead of the natural stream channels encountered previously, the San Jacinto stream network included many man-made channels and canals. Due to the flat landscape in the lower portions of the basin, a well-defined stream network was absolutely crucial in order to obtain quality results, even with the 30-meter DEM. Therefore, careful consideration was taken in the editing process, particularly in the areas surrounding control points and along the basin boundary.

The grid processing was performed entirely in Arc/Info. Since the DEM was approximately 20 million cells in size, sub-dividing the grid was not necessary. The processing time for the entire basin was approximately 10 hours. Average curve number and precipitation grids were also generated in Arc/Info using the commands listed in Chapter 4.

7.3 STREAMLINING THE METHODOLOGY

Other than the grid processing steps, the main time-consuming tasks in the methodology were the stream editing, control point placement, and the generation of the next downstream point table. There wasn't much room for improvement with regards to the stream editing since much of the work involves engineering judgment on a case-by-case basis. However, the other two tasks are fairly direct and can be automated. While this researcher performed the bulk of the data development, a WAM team member, Hudgens (1999), developed a set of tools that included steps to automate the two tasks.

7.3.1 Snapping the Control Points to the Network

As stated, the control points must be placed in the proper locations on the flow accumulation grid in order to generate the final results. Therefore, not only was there a need for a tool to snap the points to the network, but the points also had to fall on the flow direction path. Hudgen's script first generates a DEM-derived stream network. This network is generated by tracing the least-cost path on the flow direction grid from each headwater point in the single-line stream network. The fact that the network is traced from the flow direction grid means that each arc in the network falls in the middle of the flow accumulation cells, as shown in Figure 7.2.

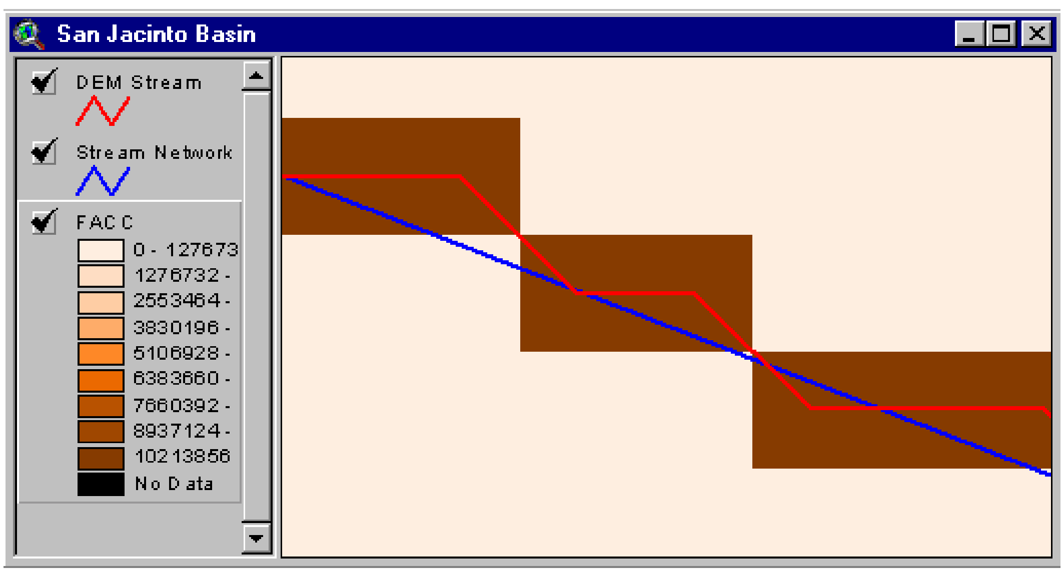

Figure 7.2: Comparison of DEM-derived stream network and single-line network.

With a stream network centered on the flow direction path, the next step in Hudgen's tools is to snap the control points to the newly created network. Since the points are snapped to a network built from the FDR grid, all the points will be on the proper flow accumulation grid cell. When the parameters are read, an accurate drainage area will be reported. The DEM-derived network can take a few hours to process, depending on the size of the network, but the snapping portion is completed in minutes. The advent of this tool alone eliminated several days of processing time.

7.3.2 Generating the Table of Downstream Control Points

Although the identification of the next downstream control point was an original parameter needed in the WAM process, it was not required by the basin contractor for the 3 previous basins in this study. Again, stream length values were used as a substitute. However, the basin contractor for the San Jacinto requested a complete set of control point parameters, including the next downstream point. In earlier research performed by Hudgens, the downstream control point table was generated manually by checking each point individually, tracing the path downstream, and recording the next control point in an Excel spreadsheet. Again, this process was tedious and required many man-hours. Therefore, during the data development process of this basin, Hudgens worked to create a tool to automate this process.

The first step was to "Build the Stream Network Connectivity." This process assigned ID values to each arc in the DEM-derived stream network. Once the arcs were labeled, the script located the next arc downstream. Finally, using the snapped control points, the script was able to identify the corresponding arc ID for the control point, and then navigated through the stream network until reaching the next downstream point. The control point ID of the downstream point was then copied into the attribute table of the snapped control points. Finally, a diagram of control point connectivity was created, as shown in Figure 7.3.

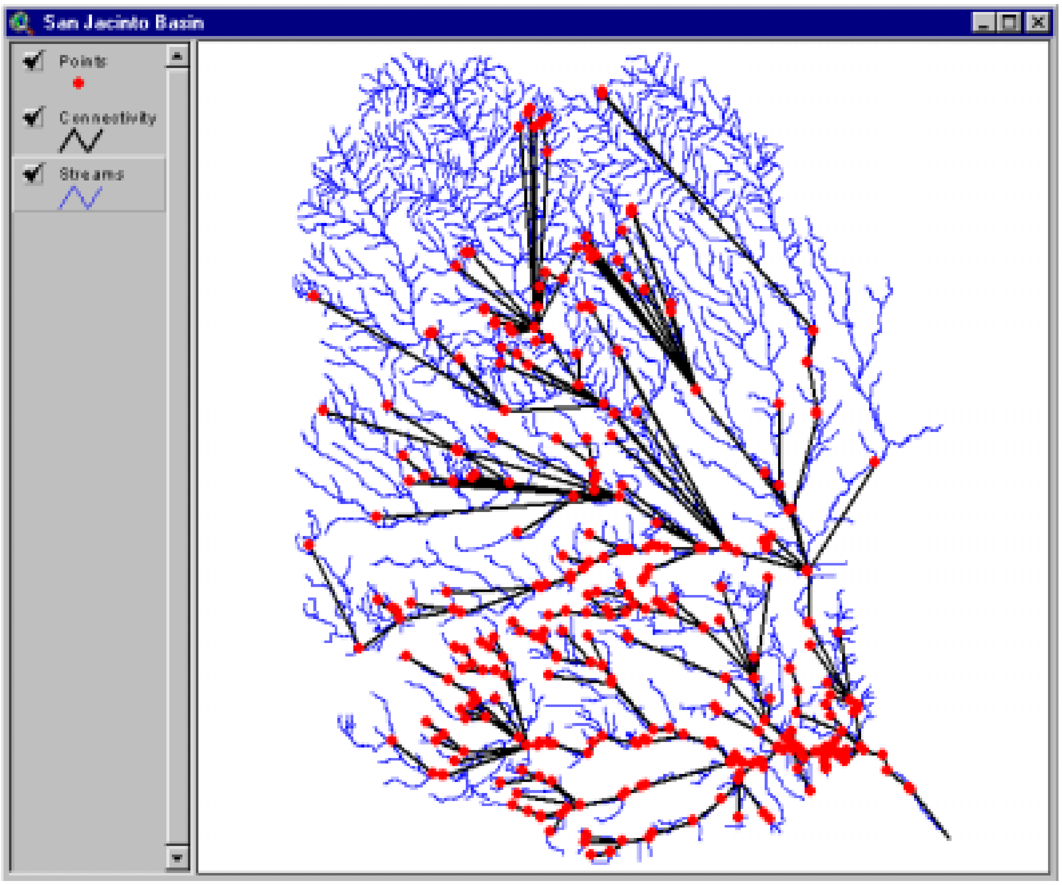

Figure 7.3: Control point connectivity diagram

7.4 San Jacinto Basin Results

The changes in the methodology for the San Jacinto basin processing were not made to improve the results of the basin parameters. Other than the two changes described, the basin processing was performed in the same manner as the Guadalupe and San Antonio basins. Although computing basin parameters was the main goal, a study of the methodology's effectiveness in dealing with areas of low relief was also an important task. The following table (7.1) contains the drainage area results for the stream gage locations in the San Jacinto basin. A complete list of results for all control points in the basin can be found in Appendix D.

Point ID	CRWR mi^2	USGS mi^2	Difference mi^2	Error %
8067650	456.88	451	6	-1.30
8068000	828.71	828	1	-0.09
8068500	403.39	409	-6	1.37
8068740	131.33	131	0	-0.25
8069000	284.47	285	-1	0.19
8070000	324.52	325	0	0.15
8070500	105.58	105	1	-0.56
8071000	117.49	117	0	-0.42
8071500	2814.02	2800	14	-0.50
8073500	284.19	293	-9	3.01
8074000	343.45	358	-15	4.06
8074500	87.91	86	2	-1.86
8075000	93.24	95	-2	1.75
8075500	65.74	63	3	-4.35
8076000	64.07	69	-5	6.75

Table 7.1: Comparison of CRWR and USGS values for San Jacinto gages.

As shown, the drainage area results for the San Jacinto basin gages were not quite as accurate as those generated for the Guadalupe and San Antonio basin.

Although most of the points fell at or below the 1% difference mark, the highlighted gages reveal significant deviance from the established values.

The main reason thought to be behind these problems was the lack of relief in the terrain. For example, the watershed slope for USGS gage 8076000 was 0.00075 m/m. Figure 7.4 shows the CRWR delineated watershed for this gage. Notice the erratic nature of the watershed boundary. Even at the 1:24,000 scale, the resolution of the data was not sufficient enough to properly represent the subtle changes in the landscape.

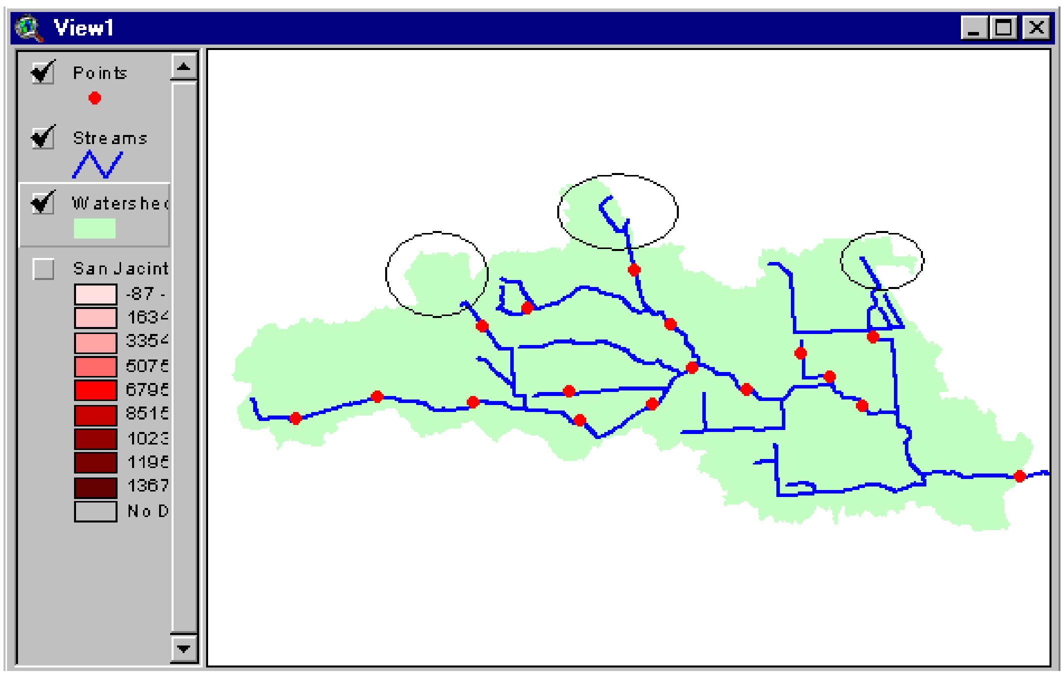

Figure 7.4: CP8076000 watershed diagram with circles denoting erratic features.

The boundary of this watershed was checked thoroughly against the DRG maps, especially around the highlighted areas. Since the terrain was so flat, no contours existed on the map to interpret if the computer delineation was correct.

The watershed boundary was so difficult to decipher from the maps that suspicion about the USGS values became a factor. The USGS values were originally developed through manual delineation from similar maps. Judgment by the person who developed the USGS value could account for the 6.75% difference in the CRWR watershed.

7.5 QUALITY CONTROL

Checking the quality of the small watersheds for the San Jacinto was also somewhat difficult. Of the 30 points below the 1000 cell threshold, only 3 were visibly incorrect and had to be delineated by hand. However, many of the tiny watersheds were in marshy areas along the coast or fell completely between two contour lines on the DRG. In such cases, there was no way to visually decipher the "true" drainage area for the point. Therefore, the drainage areas found through the grid processing were assumed to be correct for those difficult points.

7.6 CONCLUSION

The processing of the San Jacinto represented a synthesis of knowledge learned through the other case studies. For this basin, the buffered streams and 30-meter DEM were both used in an effort to generate the best possible results on the first processing run. In addition, new tools were created for placing points and generating the downstream control point table in order to offset the lengthy processing time of the 30-meter DEM.

Although the best processing techniques were used, the results for the San Jacinto basin clearly had some deficiencies. Unlike the points in the Guadalupe and San Antonio basins, several of the control points in the San Jacinto had drainage area differences above the 1-2% range. After studying the delineated watersheds for these points, it was determined that the lack of terrain relief in the basin contributed to the differences. The average slopes throughout the basin (0.0012 m/m) were so small that even the 30-meter DEM could not accurately represent small changes in the landscape. Further study on the slope limitations will follow in Chapter 8.

CHAPTER 8: RESULTS AND DISCUSSION

8.1 INTRODUCTION

One of the primary purposes of this research was to evaluate the effect of changes in the methodology used to calculate watershed parameters for the WAM. The previously established methodology used the interior single-line stream network and a 90-meter DEM of each basin for the processing. The case studies presented in Chapters 5-7 showed the advantages of adding exterior streams within the basin buffer and the using 30-meter DEMs. This chapter presents a synthesis of what was learned through these case studies and evaluates the overall accuracy of the methodology.

8.2 IMPROVED RESULTS FROM THE USE OF 30-METER DEMS

90-meter DEMs were the only available datasets for use in processing entire river basins at the start of the project. Therefore, the methodology established at the beginning of this research utilized these data files. The first runs of the Nueces, Guadalupe and San Antonio were all performed with 90-meter DEMs, but failed to produce acceptable results. The average absolute differences for the USGS gage locations in each basin were 2.22%, 3.17%, and 4.02%, respectively. Although the average differences seem relatively low, distinct differences in the control point watersheds were prominent. Along with the watershed errors, several instances of short-circuiting in the stream network were also found. These problems were anticipated since the literature indicated problems with using DEMs and stream networks of different scales.

In the early part of 1999, USGS released 30-meter data for the entire state of Texas as part of the National Elevation Dataset (NED). The seamless dataset produced improved results with its ability to more accurately represent the features of the terrain, even in areas of low relief. A comparison of the results found from the use of each dataset is shown in Figure 8.1.

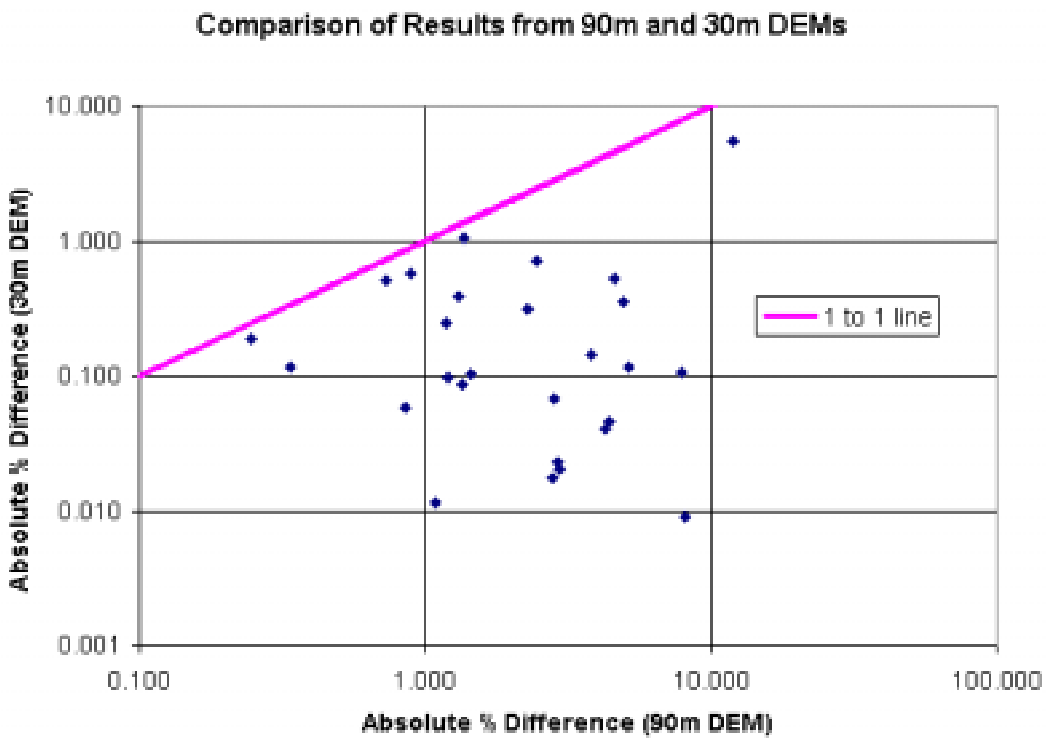

Figure 8.1: Results from the use of 30m and 90m data in the San Antonio and Guadalupe basins

In the figure, the difference in drainage area between the USGS values and CRWR values for the Guadalupe and San Antonio basins were plotted against each other on a log/log scale. Results from the Nueces basin and San Jacinto basin were not included since 30-meter data was not used on the Nueces and 90-meter data was not used on the San Jacinto.

The fact that all the points fell well below the 1-to-1 line shows that the use of 30-meter DEMs improved the drainage area results. The average percent difference in drainage areas across both basins was 3.08% for the results generated from 90-meter data while the 30-meter data produced an average percent difference of 0.42% for the same control points. Using the 90-meter DEMs, 22 of the control points had an absolute difference greater than 1% while only 2 points remained above 1% after incorporating the 30-meter DEMs. Further statistics on the data is shown in Table 8.1.

Statistic	**90-meter**	**30-meter**
Mean	3.08	0.42
Standard Deviation	2.75	1.05
Range	11.69	5.52
Minimum	0.24	0.01
Maximum	11.94	5.53

Table 8.1: Statistical summary of % difference in results for 90-meter and 30-meter data.

The use 30-meter DEMs improved the results on several levels. Not only did the data improve results for the larger, USGS watersheds by more clearly defining basin boundaries, but the data also improved intermediate watersheds by eliminating virtually all instances of short-circuiting in the stream network. Clearly, the fine scale DEM (1:24,000) more accurately matched the features of the terrain and the 1:100,000 scale stream network. The effect of 30-meter data on the small, quality control watersheds is shown later in this chapter.

The only drawback found from using 30-meter data was the significant increase in both file size and processing time of the DEM. For example, the DEM file size for the San Antonio increased from 2.2 MB to 43 MB, while the flow accumulation grid increased from 27 MB to 239 MB. The DEM processing time rose from approximately 1 hour to almost 15 hours. Dividing larger basin DEMs into smaller parts at the beginning of the process, as described in Chapter 6, can reduce the total processing time significantly. If file size or processing time is a restriction, 90-meter DEMs can be used with buffered streams to produce acceptable results, as shown in the next section.

8.3 USE OF BUFFERED STREAMS

For the first effort in processing the DEM for the Nueces basin, the constructed stream network contained only the streams that fell within the established basin boundary. However, the DEM was buffered a distance of 10 kilometers in order to allow the methodology to determine its own boundary from the data itself. Upon checking the delineated watersheds from the first run, it was clear that many watersheds meandered outside of the basin boundary. This resulted in large differences for many of the drainage area values. Several solutions were considered, including clipping the DEM to the original basin boundary and building an artificial wall in the DEM along the basin boundary. However, the solution decided upon was to “burn” additional streams into the basin buffer.

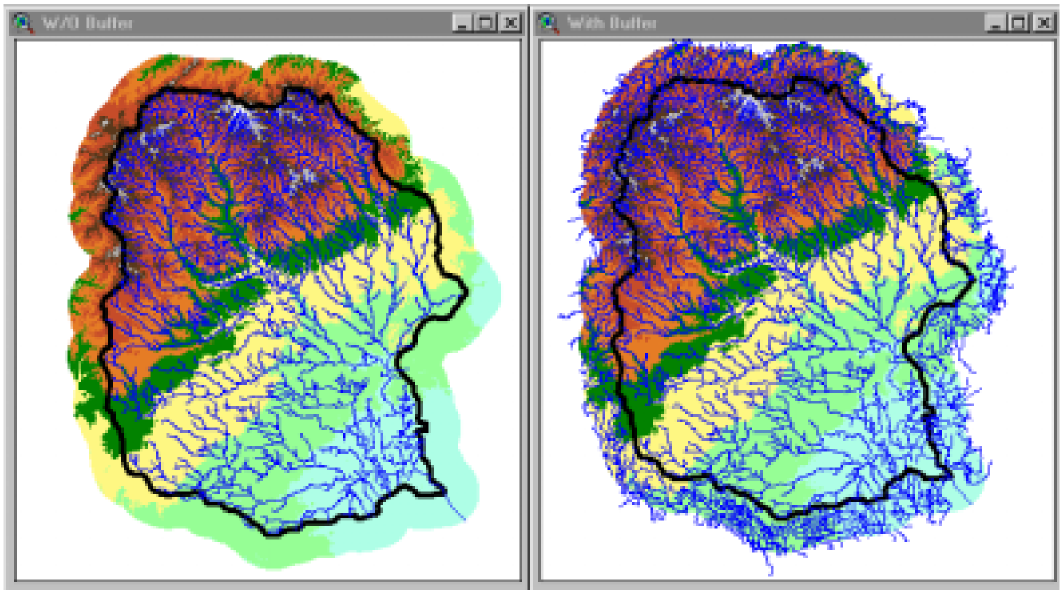

Figure 8.2: San Jacinto basin without (left) and with (right) buffered streams.

Intuitively, the results for control point watersheds within the interior of the basin would not be affected by the use of buffered streams. However, the addition of the streams would affect those control point watersheds that exist jointly with the basin boundary. Drainage area results were generated with and without buffered streams for the control points in the Nueces and San Antonio basins. The results were plotted against each other on a log/log graph for comparison with a 1-to-1 line, as shown in Figure 8.3.

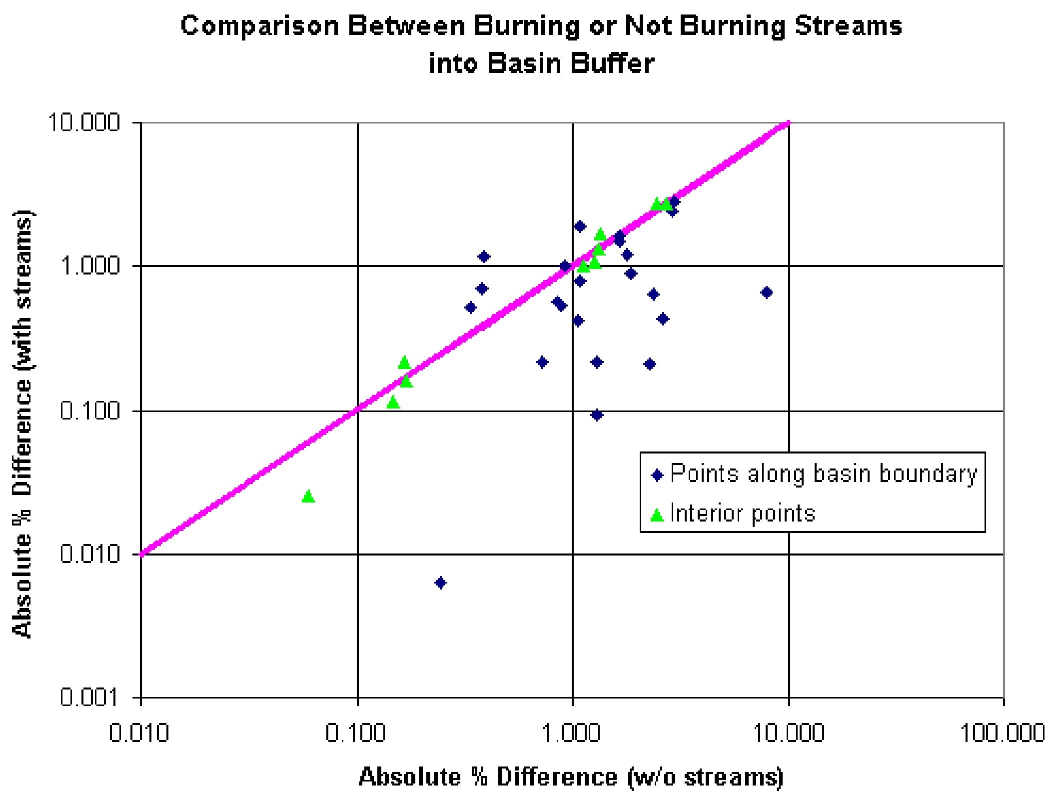

Figure 8.3: Results from burning and not burning streams in the Nueces and San Antonio

Points falling below the line represent improvement in drainage area difference by the use of buffered streams. As shown, the addition of the streams within the buffered area provided a significant reduction in absolute drainage area difference across the control point watersheds, with the average percent difference dropping from 1.50% to 0.96%. Of course, the most significant improvement was found for points whose watersheds were directly affected by changes in the basin boundary. Watersheds in the interior portion of the basin fell along the 1-to-1 line, meaning the addition of buffered streams did not improve the results of these points. A few of the points fell above the line, meaning a few watersheds actually had worse results after adding streams. One possible explanation for this may be that the USGS value used for comparison was wrong in the first place. So, when the drainage area was reduced by the buffered streams, the percent difference in drainage area became greater. Table 8.2 shows a statistical analysis of the results for both scenarios.

Statistic	W/O	With
Mean	1.50	0.96
Standard Deviation	1.44	0.83
Range	7.87	2.81
Minimum	0.06	0.01
Maximum	7.93	2.82

Table 8.2: Statistical summary of difference in results for burning and not burning streams.

8.4 ANALYSIS OF DEGREE OF TERRAIN RELIEF

At the outset of this research, the literature reviewed stated the success of automated terrain analysis techniques in areas with well-established drainage. However, several authors expressed caution when using automated techniques in areas of low relief, such as the coastal region of Texas. With the amount of watersheds studied in this thesis, significant data existed to test the ability of both 90-meter and 30-meter data to accurately delineate watersheds for varying levels of relief.

For both the Nueces and San Antonio basins, slopes were calculated for each of the USGS gage watersheds using 90-meter data. Elevations were read from the DEM at the upper and lower end of each watershed, and the flow length for each was found using Arcview tools. The slopes were then plotted against the absolute percent differences in the drainage area results to see if there was a correlation between terrain slope and accuracy of results, as shown in Figure 8.4.

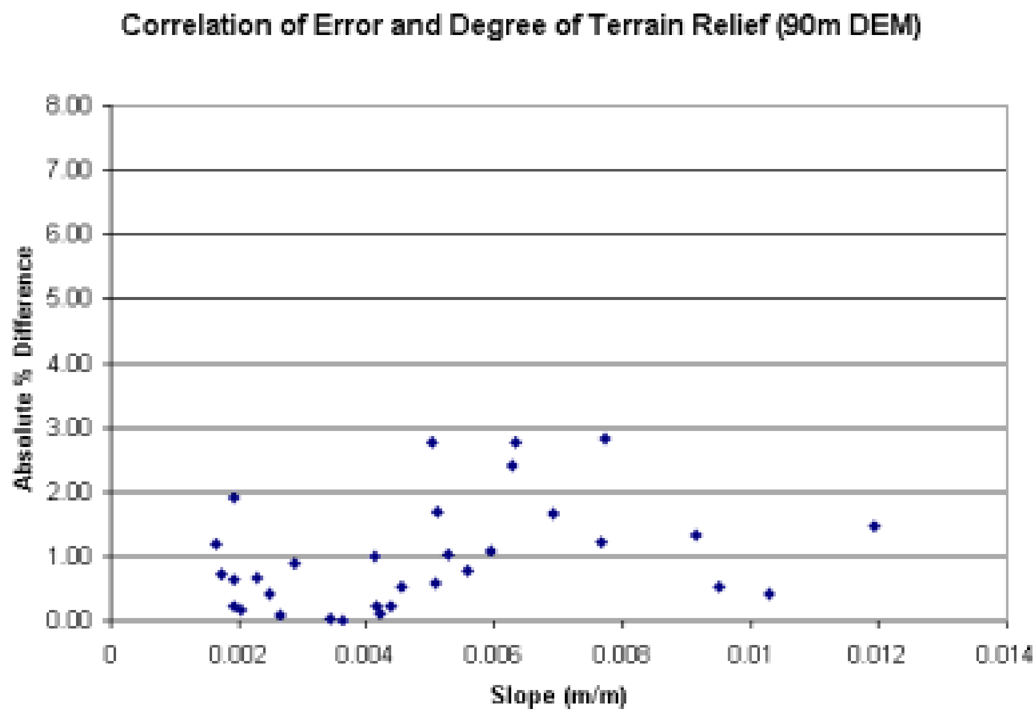

Figure 8.4: Effect of slope on absolute % difference in drainage area (90m).

Clearly, there was no correlation between slope and absolute difference for the 90-meter DEM results. The main reason for the lack of correlation is that many factors besides slope affect the accuracy of the 90-meter DEM results. Many differences can be contributed to short-circuiting and the lack of cohesiveness between the 1:250,000 scale DEMs and 1:100,000 scale stream network.

A similar study was also performed for results obtained from 30-meter DEMs. Watershed slopes were calculated in the same manner for the Guadalupe, San Antonio, and San Jacinto river basins. The addition of slope values from the San Jacinto basin allowed for an insight into areas of particularly low relief. Figure 8.5 is a summary of the results obtained from this analysis.

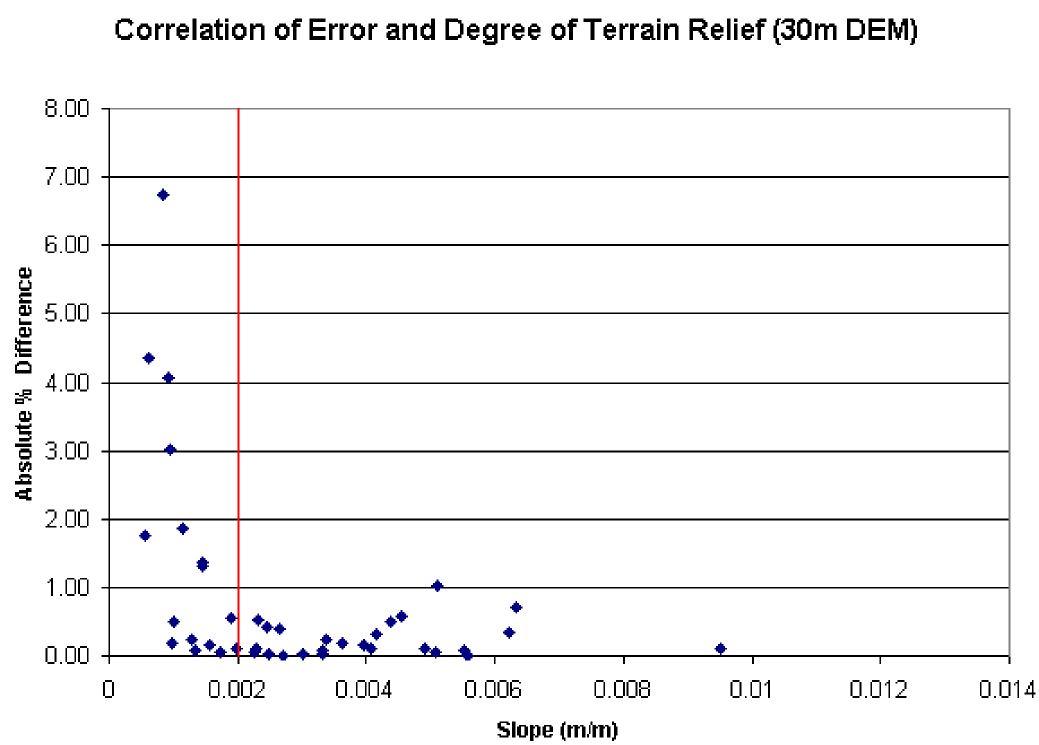

Figure 8.5: Effect of slope on absolute % difference in drainage areas (30m).

Figure 8.5 shows a clear correlation between slope and absolute drainage area difference for 30-meter data. All watersheds with a slope greater than 0.002 m/m had an absolute difference less than or equal to 1%. However, once slopes reached 0.002 m/m, a steep increase in absolute difference was apparent. A majority of the slopes below this threshold were found in the coastal regions of the San Jacinto basin, which has an overall basin slope of 0.00082 m/m. The following table (8.3) contains statistical data on slope for the 4 basins studied.

The total area and basin slope represent values for each basin as a whole. The average area and average slope represent values for the individually delineated watersheds in the basin.

Basin	**Total Area (mi^2)**	**Avg. Area (mi^2)**	**# of Points**	**Basin Slope**	**Avg. Slope**	**Avg/Basin Slope Ratio**
Nueces	16749	3742	21	0.0016	0.0050	3.13
Guadalupe	5982	1342	14	0.0023	0.0034	1.48
San Antonio	4195	956	13	0.0026	0.0047	1.81
San Jacinto	3954	426	15	0.0008	0.0012	1.46
Average	*7720*	*1617*	*16*	*0.0018*	*0.0036*	*1.97*

Table 8.3: Representative slopes of the 4 basins within the study area.

As shown, the average slope of a delineated watershed is twice that of the basin slope. Thus, most of the points within the basin still fall in areas with well-defined drainage. With all 4 basins draining to the Texas coastline, the flattening occurs only in the lower portion of the basin, which is where most of the drainage area differences exist.

Further research was done to determine the threshold limit of distance from the coast at which the problems with terrain slope occur. Figure 8.6 shows that slopes below 0.002 m/m occur within 75 miles from the coast. Therefore, although 30-meter DEMs produce accurate results for most cases, this study reveals some limitations when working in areas of significantly low terrain relief.

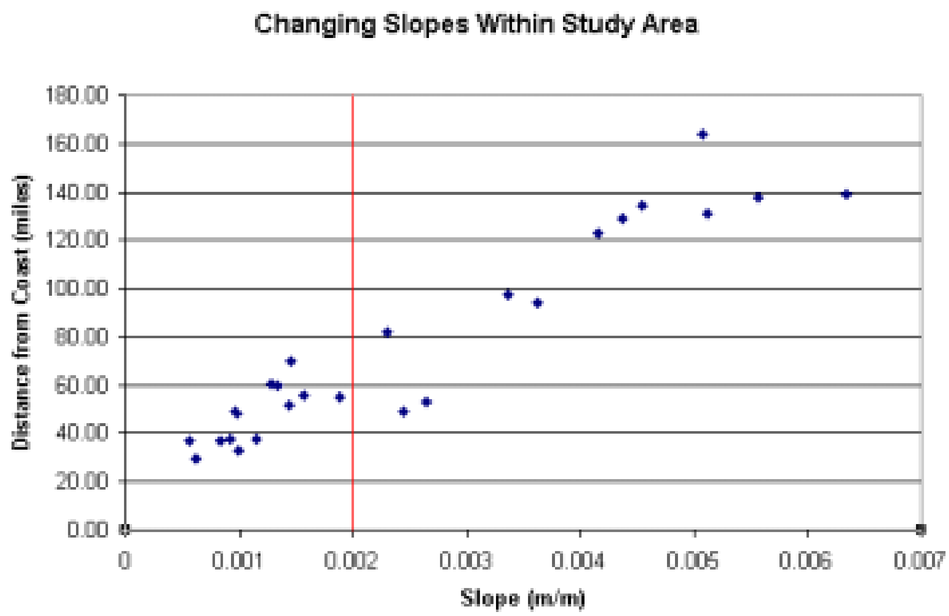

Figure 8.6: Analysis of slope as a function of distance from coast.

8.5 QUALITY CONTROL

The final issue studied in this thesis was the effect of DEM resolution on the quality control required for the datasets. At the outset of this research, a threshold of 1000 cells was used as a benchmark for checking the smaller watersheds in the basin. This cell count represents approximately 3 square miles for 90-meter data and 0.3 square miles for 30-meter data. Therefore, all watersheds below 3 square miles (or 0.3 square miles) were checked visually against the DRGs for errors in watershed delineation. If errors were found, a new watershed for that control point was delineated by hand from the DRGs. Since the 1000 cell value was chosen somewhat arbitrarily, a study of its validity was performed for this thesis.

For this study, error represents the absolute percent difference between the computer generated value and the hand-delineated value. Upon studying the results obtained from the 90-meter data in the Nueces, Guadalupe, and San Antonio basins, approximately 60 watersheds below the 1000 cell threshold were delineated manually. The results from this study have been plotted in Figure 8.7.

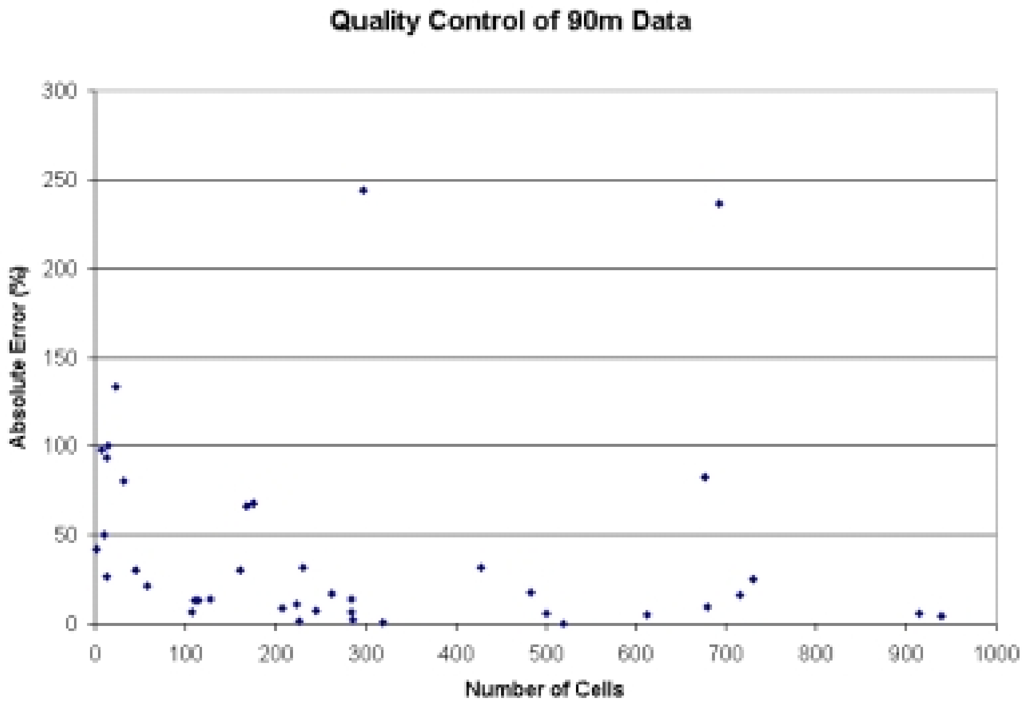

Figure 8.7: Plot of results from 90m DEM for small watersheds.

The general trend in the data shows an increase in error below approximately 200 cells, which corresponds to an area of 0.6 square miles. However, no clear conclusion can be made from this figure, especially since many of the errors are above 25%. Inconsistency in the results can be attributed to the lack of density in the 1:100,000 scale stream network. For example, when comparing the stream network with the 1:24,000 scale DRGs, many small streams necessary to define the watersheds were missing from the 1:100,000 scale network. Also, many of the existing streams in the network ended without continuing to the furthest extent of the matching streams shown on the DRG. Often, these deficiencies were the cause of incorrect watershed delineation.

The same study described above was also performed on the results generated from the 30-meter DEM. Twenty-five watersheds with a flow accumulation of less than 1000 cells in the Guadalupe and San Antonio basins were delineated manually and compared to the automated delineation. Since the 1000 cell threshold for 30-meter data corresponds to a much smaller drainage area than that of the 90-meter data, it was anticipated that an increase in this threshold would be required. Figure 8.8 shows the plot of results for the 30-meter data.

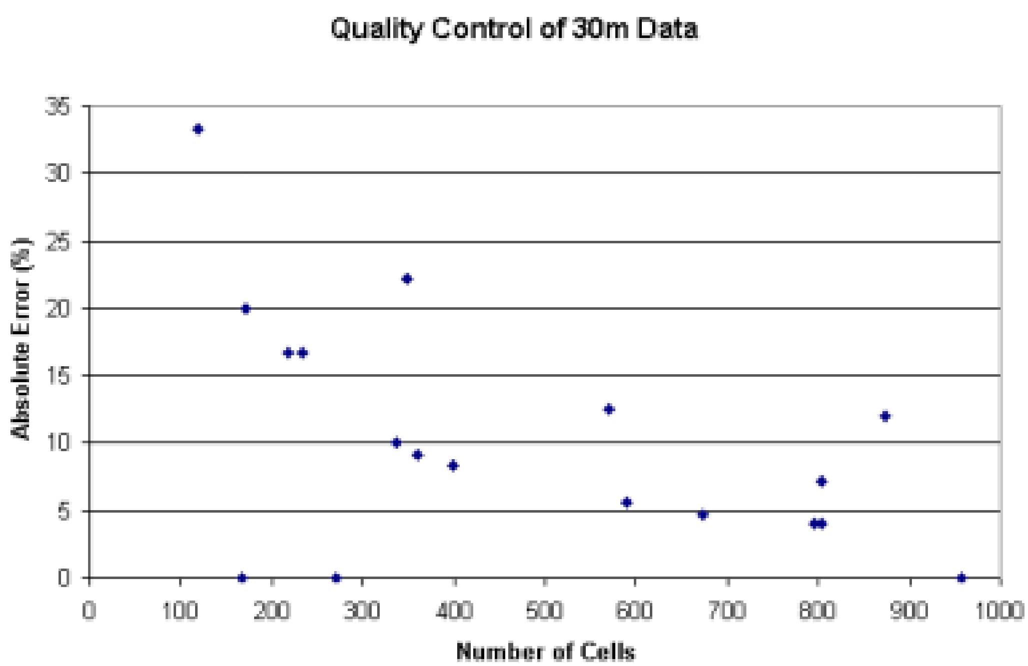

Figure 8.8: Plot of results from 30m DEM for small watersheds.

The results obtained from the study of 30-meter data revealed a clear trend, with the error increasing for watersheds below approximately 400 cells or 0.15 square miles. From the graph, however, it is shown that the error does not close to zero at 1000 cells. Ordinarily, this would suggest that drainage areas of greater than 1000 cells should be checked until the percent error is eliminated. However, in watersheds of this size, five percent error corresponds to a drainage area difference of roughly 0.01 square miles. Clearly, the results show that the 30-meter DEM has the ability to more accurately read small changes in the terrain.

As stated in Chapter 7, clear delineations could not be performed for the small watersheds in the San Jacinto basin due to a lack of contours on the DRGs in the flat areas. Therefore, without a clear basis for judging the accuracy of these watersheds, the San Jacinto basin results were not included in the quality control study.

8.6 CONCLUSION

The purpose of this research was to not only generate watershed parameters, but also to study how changes in the methodology would affect the results. The results showed that adding streams to the buffered area and incorporating the use of 30-meter data had a profound effect on the calculated parameters. Further discussion of the results and recommendations for future work on this project follow in Chapter 9.

CHAPTER 9: CONCLUSIONS AND RECOMMENDATIONS

This thesis analyzes an approach for calculating watershed parameters for control point locations in State of Texas. GIS is used in the calculation of the parameters, which are used as input into a water availability model, WRAP. First, the EPA's river reach file is edited to produce a single-line stream network for each river basin in the study area. During the stream editing process, TNRCC and the basin contractor build a control point coverage that includes water right, return flow, water quality and USGS stream gage locations. Once the stream network and control points are complete, a digital elevation model is built and processed using CRWR-prepro. Next, average curve number and precipitation grids are created. Then, watersheds for each control point are delineated from the processed DEM, and the parameters are extracted from the flow accumulation, CN, and precipitation grids. Finally, a script is run to locate the next downstream point for each of the control points. The methodology was used to generate results for 4 river basins in Texas: Nueces, Guadalupe, San Antonio, and San Jacinto. Case studies were presented for each basin.

In each case study, changes in the methodology were made as problems were encountered. For the Nueces, many of the watersheds along the outskirts of the basin captured area from the adjacent basin. To remedy this problem, exterior streams that fell within the 10km basin buffer were merged with the interior stream network of the basin and burned into the DEM. The additional streams in the buffer served to carry water away from the boundary and produced watersheds that more accurately fit the established basin boundary. The average error in drainage area across the basin was reduced from 1.5% to 0.96%. The most improvement was found along the outer portion of the basin, while the interior watersheds remained unchanged.

The Guadalupe and San Antonio basins were studied jointly since both basins were processed simultaneously in the project time-line. Therefore, the changes in methodology were applied to both at the same time. The first attempt at generating watershed parameters was made using 90-meter DEMs (1:250,000 scale). Although complications were expected from using 1:250,000 DEMs with 1:100,000 scale river networks, the 90-meter DEMs were the best available data source at the time. However, soon after the first run was completed, 30-meter (1:24,000 scale) DEMs became available for the entire state as part of the National Elevation Dataset (NED). Since many errors existed in the results generated from 90-meter DEMs, the new 30-meter DEMs were incorporated into the methodology and produced very accurate results. The average error in drainage areas across the basin was reduced from 3.08% to 0.42%. The study showed that the finer resolution DEMs were able to accurately delineate watersheds of every size in the basin, ranging from approximately 10,000 square miles to 0.15 square miles.

For the final case study, all the changes made in the Nueces, Guadalupe, and San Antonio basins were applied to the processing of the San Jacinto basin. In addition, newly created tools were used to automatically snap control points to the stream network and to locate the next point downstream of each control point.

Also, since the San Jacinto is located in the coastal region of the state, an analysis was made of the accuracy of the methodology in areas of low relief. Although no correlation existed between slope and percent error with 90-meter data, it was found that the use of 30-meter DEMs in the methodology produced accurate results in areas with slopes above approximately 0.002 m/m, which generally occur within 75 miles of the coast. Below that level of relief, confidence in the results was questionable.

The quality control procedures for the methodology were also studied in this research. When using 90-meter data, the flow accumulation grid has to be checked for the existence of short-circuiting. Also, watersheds below a flow accumulation of 1000 cells must be checked for errors in the automated delineation. Many of the errors in small watersheds can be lessened by careful construction of the stream network. However, when using 30-meter data, all instances of short-circuiting were eliminated. Also, the study showed that the cell threshold for checking watersheds could be reduced to approximately 400 cells, which corresponds to a drainage area of 0.14 square miles.

Clearly, this study has shown that the accuracy of the methodology is highly dependant on the source data used. However, after analyzing and changing the methodology, a few limitations exist. The main limitation of using 30-meter data is the significant increase in both file size and processing time, which each increased more than 10-fold when compared to those for 90-meter data. The study found that DEMs with less than 20 million cells are manageable. Those larger should be sub-divided using the methods presented in Chapter 6. Also, results from the San Jacinto indicated the possibility of limitations in areas of low relief. With the inclusion of more coastal basins in the WAM project, more studies on the effectiveness of the methodology in these areas must be made. Since the coastal basins are relatively small compared to other basins in the state, it may be possible to use 10-meter DEMs in these areas. A third limitation is the lack of density in the RF3 files. By comparing the 1:100,000 scale river network to the 1:24,000 scale DRGs, it is clear than many streams important to the drainage features of the terrain are missing in the RF3. However, since the completion of this research, EPA has released the National Hydrography Dataset (NHD). Although the network is still at the 1:100,000 scale, it has been described as a more complete and accurate stream network. Also, the Texas Water Development Board is working on a 1:24,000 scale stream network for the state. Upon completion, the incorporation of the 1:24,000 scale network should eliminate many errors in the smaller watersheds, and should be helpful in defining the drainage features of the flat, coastal basins.

APPENDIX A: NUECES BASIN RESULTS

A.1 INTRODUCTION

The following appendix contains a table of watershed parameters for all of the control points in the Nueces River basin. The table includes the control point identification number, type of control point, drainage area in square miles, flowlength to outlet in miles, and the x and y coordinates of the control point location based on the TSMS Albers projection described in Chapter 3.

ID	Type	Area (mi^2)	Flowlength (mi)	X-coord.	Y-coord.
1	Stream gage	757.35	368.23	1000279	806937
2	Stream gage	687.10	399.27	976890	812828
3	Stream gage	1863.16	333.81	1010296	773118
4	Stream gage	4045.47	260.92	1031068	703970
5	Stream gage	5193.11	218.54	1074304	695931
6	Stream gage	8144.20	139.44	1141375	683607
7	Stream gage	393.18	327.22	1028577	813632
8	Stream gage	124.32	330.62	1021156	815410
9	Stream gage	637.42	297.20	1031624	786619
10	Other primary	33.96	300.58	1021726	792426
12	Stream gage	208.49	309.74	1049103	814008
13	Stream gage	246.82	289.79	1050368	794439
15	Other primary	4.39	306.90	1054050	809233
16	Stream gage	45.19	305.20	1057745	823187
17	Stream gage	165.23	280.79	1068993	800752
18	Stream gage	97.42	308.87	1072852	822830
19	Stream gage	153.20	288.43	1082194	803040
21	Other primary	57.46	302.15	1089165	819406
22	Other primary	105.08	288.83	1084854	804956
24	Stream gage	138.99	285.79	1024928	776535
25	Stream gage	3428.13	218.59	1083474	730503
26	Stream gage	784.26	148.03	1142083	714461
27	Other primary	5478.07	112.59	1171812	703553
28	Stream gage	1148.67	123.17	1167579	718729
29	Stream gage	15460.55	101.80	1177579	698281
30	Stream gage	16542.09	50.55	1210240	654689
31	Stream gage	16720.74	18.80	1233645	637945
111	Other primary	8.53	301.03	1037201	805844
112	Other primary	23.24	301.58	1038747	806934
141	Other primary	15.64	301.39	1041980	808286
142	Other primary	2.39	301.96	1044418	808545
201	Other primary	1.81	295.58	1077078	808311
202	Other primary	10.19	287.88	1072485	808585
231	Other primary	33.36	286.83	1094630	807107
232	Other primary	13.52	288.87	1098448	807630
991	Confluence	4450.24	238.75	1052394	693798
992	Confluence	4045.47	261.00	1030928	704077
993	Confluence	4426.69	248.43	1044158	701838

994	Confluence	7985.91	155.91	1127661	670900
995	Confluence	8072.20	146.88	1134454	678406
996	Confluence	658.52	224.06	1077805	733896
997	Confluence	3575.37	204.74	1095442	717202
998	Confluence	4245.27	168.40	1124277	700117
999	Confluence	828.12	145.21	1145472	714107
9910	Confluence	1532.65	245.47	1074369	757739
9911	Confluence	435.51	274.25	1051143	777500
9912	Confluence	518.71	266.84	1089645	783029
9913	Confluence	128.59	287.95	1023008	778543
12103745001	Diversion point	62.46	297.73	1086836	815531
12103806001	Diversion point	61.53	299.96	1058293	816846
12103878001	Diversion point	70.54	360.82	1030339	848477
12103878002	Diversion point	11.94	361.77	1031326	849033
12103884001	Diversion point	155.28	206.50	1102604	764066
12103903001	Diversion point	3461.83	215.12	1087447	727851
12103910001	Diversion point	20.39	226.34	1085165	611184
12103910301	Other secondary	20.39	226.34	1085165	611184
12103913001	Diversion point	13.98	343.02	1001863	774081
12103913301	Other secondary	13.98	343.02	1001863	774081
12103914001	Diversion point	44.55	256.19	1061891	758511
12103919001	Diversion point	4.95	175.49	1115675	732515
12103954001	Diversion point	518.85	266.51	1090011	782657
12103957001	Diversion point	54.50	402.87	989671	843931
12103978001	Diversion point	41.81	416.96	1005485	852446
12103978002	Diversion point	40.22	417.19	1005748	852677
12103978003	Diversion point	1.51	417.12	1005553	852629
12103978004	Diversion point	1.38	417.22	1005400	852800
12103986001	Diversion point	24.51	216.78	1119644	780861
12103986002	Diversion point	1.08	217.26	1119973	780476
12103986301	Other secondary	1.08	217.26	1119973	780479
12103988001	Diversion point	6.64	292.25	1018085	780236
12103988002	Diversion point	6.54	292.69	1017733	780443
12103989001	Diversion point	6.61	292.32	1018056	780343
12103989002	Diversion point	6.58	292.58	1017826	780505
12103990001	Diversion point	14.51	291.88	1018475	780231
12103991001	Diversion point	3.14	292.96	1017378	780327
12103991401	Other secondary	0.01	292.74	1017647	780402
12104006001	Diversion point	60.74	409.04	989283	849215
12104008001	Diversion point	338.33	401.96	997014	844693

12104014310	Other secondary	3340.00	221.41	1080271	731506
12104041001	Diversion point	145.84	209.18	1102902	767682
12104094001	Diversion point	28.12	371.90	1023057	862329
12104113001	Diversion point	154.21	207.24	1102640	765108
12104169001	Diversion point	3.86	402.41	1006074	842193
12104169002	Diversion point	3.79	402.57	1006240	842067
12104169003	Diversion point	3.67	402.77	1006456	842215
12104169004	Diversion point	0.73	403.04	1006887	842239
12104169005	Diversion point	0.66	403.21	1007117	842168
12104169006	Diversion point	0.55	403.50	1007397	842128
12104169101	Other secondary	3.87	402.35	1005967	842212
12104169201	Other secondary	0.29	403.61	1007637	842186
12104177001	Diversion point	432.43	312.40	1033417	799429
12104238001	Diversion point	349.44	333.45	1026942	819787
12104238002	Diversion point	341.67	333.66	1026684	819923
12104238003	Diversion point	341.43	334.39	1026254	820830
12104278001	Diversion point	17.30	414.76	987694	853989
12104286001	Diversion point	51.56	220.99	1109895	779353
12104304001	Diversion point	129.04	287.74	1022991	778258
12104305001	Diversion point	431.42	312.93	1033539	800206
12104310001	Diversion point	246.42	264.34	1038144	753983
12104339001	Diversion point	242.71	267.35	1037122	757614
12104352001	Diversion point	34.07	318.05	1048278	822571
12104352002	Diversion point	33.61	318.24	1048190	822767
12104352003	Diversion point	33.48	318.42	1048078	823077
12104352004	Diversion point	33.37	318.61	1048007	823296
12104365001	Diversion point	12.05	409.90	975683	819658
12104402001	Diversion point	16540.85	51.13	1209473	654977
12104402501	Return flow	16540.85	51.13	1209472	654978
12104405001	Diversion point	0.21	393.32	998571	834853
12104413001	Diversion point	3.93	402.28	1005851	842124
12104505001	Diversion point	131.25	323.76	1045374	827463
12104505002	Diversion point	131.25	323.76	1045356	827471
12104506001	Diversion point	407.92	271.76	1091165	789110
12105009001	Diversion point	103.77	361.79	1021333	850876
12105009002	Diversion point	79.17	363.14	1021565	852384
12105063001	Diversion point	379.73	331.38	1028907	817715
12105063002	Diversion point	379.70	331.49	1028851	817889
12105065401	Other secondary	0.15	103.15	1177182	700585
12105145001	Diversion point	1.70	149.81	1145715	719692

12105145002	Diversion point	0.14	145.69	1148395	723560
12105170310	Other secondary	8.45	169.02	1114372	680838
12105186001	Diversion point	74.09	327.86	1045036	832342
12105192001	Diversion point	5.49	286.42	1075296	795872
12105201001	Diversion point	33.81	322.99	987589	713284
12105204001	Diversion point	61.66	332.20	1043365	837163
12105241001	Diversion point	379.75	331.27	1028904	817501
12105247001	Diversion point	163.66	203.59	1102369	760211
12105248001	Diversion point	165.89	202.96	1102148	759510
12105249001	Diversion point	166.32	202.35	1102069	758609
12105258001	Diversion point	1391.99	111.10	1175555	707885
12105297310	Diversion point	50.64	291.60	1021549	782579
12105304001	Diversion point	340.66	335.44	1026414	822254
12105305001	Diversion point	0.92	319.61	1053204	838548
12105325001	Diversion point	138.81	318.68	1047032	821942
12105344001	Diversion point	51.49	221.05	1109920	779447
12105344002	Diversion point	13.91	221.25	1109973	779669
12105372001	Diversion point	316.07	341.66	1024916	827786
12105398001	Diversion point	42.15	278.00	1054377	781066
12105398002	Diversion point	1.47	280.05	1056424	780750
12105398003	Diversion point	1.20	280.24	1056893	780895
12105420001	Diversion point	162.78	283.54	1088062	801165
12105420501	Return flow	162.95	283.47	1088109	801110
12105475001	Diversion point	2.70	338.13	1040415	843920
12105475002	Diversion point	1.78	339.44	1039322	844887
12105497001	Diversion point	385.59	329.16	1028683	815560
12105509001	Diversion point	12.70	17.70	1233662	639472
12105509002	Diversion point	11.79	18.52	1234926	639557
12105509003	Diversion point	8.53	19.22	1235965	639586
12105511001	Diversion point	0.02	136.94	1156036	729414
12105511002	Diversion point	0.37	138.85	1154226	730512
12105511003	Diversion point	0.73	136.95	1156492	729844
12105511004	Diversion point	0.60	136.82	1156319	729649
12105511301	Other secondary	0.02	136.94	1156034	729414
12105511501	Return flow	0.02	136.90	1156170	729404
12105511502	Return flow	2.82	138.41	1153759	729538
12105511503	Return flow	0.02	136.94	1156037	729414
12105561001	Diversion point	2.57	60.61	1211625	662175
12105575001	Diversion point	19.53	340.46	1040874	847406
12105575002	Diversion point	3.45	340.54	1040768	847495

62102464001	Diversion point	16720.74	18.80	1233644	637951
62102464002	Diversion point	16540.82	51.18	1209379	654970
62102465001	Diversion point	0.01	55.04	1217573	663322
62102465002	Diversion point	0.01	55.04	1217608	663376
62102465301	Other secondary	0.01	55.04	1217608	663376
62102466001	Diversion point	16719.37	20.39	1232529	635956
62102467001	Diversion point	16765.07	16.76	1234708	639109
62102467002	Diversion point	16764.77	17.29	1233802	639101
62102468001	Diversion point	16766.43	15.13	1235232	637046
62102468002	Diversion point	16765.96	15.57	1235212	637734
62102469001	Diversion point	16765.89	15.62	1235222	637806
62102469002	Diversion point	16766.39	15.19	1235217	637089
62102469002	Diversion point	16766.39	15.19	1235224	637081
62103016001	Diversion point	92.27	420.54	1002812	864437
62103016002	Diversion point	90.02	420.77	1002886	864707
62103017001	Diversion point	13.92	414.81	998837	859827
62103018001	Diversion point	16.92	419.42	1007641	851779
62103018002	Diversion point	16.92	419.42	1007568	851844
62103019001	Diversion point	0.10	415.36	1004365	851854
62103019002	Diversion point	42.12	416.33	1005589	851544
62103020001	Diversion point	62.72	410.05	1001182	852177
62103020002	Diversion point	61.07	410.91	1001674	853001
62103020003	Diversion point	52.32	413.34	1002493	851763
62103020004	Diversion point	52.19	413.72	1002808	851474
62103021001	Diversion point	62.79	409.97	1001124	852049
62103021002	Diversion point	63.24	409.71	1000779	851858
62103021003	Diversion point	64.51	408.69	999765	851185
62103021004	Diversion point	64.55	408.53	999693	851398
62103022001	Diversion point	0.05	405.31	998867	847866
62103022002	Diversion point	256.63	406.51	998307	849590
62103023001	Diversion point	324.33	405.57	998456	848231
62103024001	Diversion point	0.65	401.64	996821	844125
62103025001	Diversion point	3.40	404.60	1002261	845384
62103025002	Diversion point	2.80	404.94	1002732	845547
62103025003	Diversion point	2.67	405.15	1002999	845719
62103026001	Diversion point	4.18	404.07	1001630	845133
62103027310	Other secondary	4.57	403.79	1001179	844941
62103028001	Diversion point	7.83	402.59	1000349	843715
62103028002	Diversion point	7.70	402.77	1000606	843784
62103029001	Diversion point	358.14	397.66	997130	839442

62103034001	Diversion point	360.03	396.09	996714	837979
62103036001	Diversion point	360.58	395.46	997154	837201
62103037001	Diversion point	361.89	395.07	996917	836662
62103038001	Diversion point	29.20	413.84	988384	853115
62103039001	Diversion point	57.41	411.01	989995	851353
62103039002	Diversion point	57.06	411.27	990005	851759
62103039003	Diversion point	31.11	412.06	989360	852087
62103040001	Diversion point	63.35	407.63	990990	848316
62103040002	Diversion point	60.99	408.68	989615	848805
62103041001	Diversion point	63.35	407.63	990988	848317
62103041002	Diversion point	63.04	408.03	990477	848347
62103041003	Diversion point	60.99	408.68	989615	848805
62103042001	Diversion point	63.35	407.63	990987	848317
62103043001	Diversion point	73.24	403.75	991558	844197
62103043002	Diversion point	72.86	404.01	991521	844539
62103044001	Diversion point	43.84	405.99	986517	845998
62103044002	Diversion point	32.53	408.01	984393	845971
62103044003	Diversion point	5.05	409.02	983199	845839
62103046001	Diversion point	133.80	399.66	992268	840404
62103047001	Diversion point	0.95	407.47	989702	833341
62103048001	Diversion point	165.24	398.33	993288	838890
62103048002	Diversion point	165.17	398.41	993195	838980
62103049001	Diversion point	176.12	395.26	995681	836456
62103049002	Diversion point	176.67	394.84	996150	836071
62103049003	Diversion point	177.36	393.74	997457	835223
62103049004	Diversion point	579.03	390.60	997893	831909
62103050001	Diversion point	0.51	402.63	1007926	839186
62103051001	Diversion point	3.42	401.01	1006118	839835
62103052001	Diversion point	3.43	400.96	1006081	839835
62103053001	Diversion point	3.43	400.96	1006078	839836
62103054001	Diversion point	3.42	401.01	1006086	839835
62103055001	Diversion point	3.93	402.28	1005851	842124
62103055002	Diversion point	3.82	402.46	1006110	842170
62103056001	Diversion point	8.93	400.52	1004689	840060
62103057001	Diversion point	8.93	400.52	1004687	840070
62103058001	Diversion point	570.19	392.33	997910	833714
62103059001	Diversion point	576.91	391.54	997088	833019
62103060001	Diversion point	578.17	391.00	997587	832237
62103060002	Diversion point	577.06	391.28	997261	832710
62103061001	Diversion point	580.49	390.21	998145	831415

62103062001	Diversion point	608.51	388.51	999259	829465
62103063001	Diversion point	610.12	387.29	999051	827974
62103064001	Diversion point	610.29	387.14	999240	827830
62103065001	Diversion point	629.01	382.78	1000592	822403
62103066001	Diversion point	0.66	379.09	999026	818791
62103067001	Diversion point	766.59	365.16	999597	803275
62103068001	Diversion point	787.64	361.65	1001294	800075
62103069001	Diversion point	789.61	358.90	1003753	798142
62103070001	Diversion point	398.30	437.10	961681	840737
62103070002	Diversion point	383.11	438.52	962295	842204
62103071001	Diversion point	661.26	404.99	971779	816329
62103072001	Diversion point	1862.67	334.31	1010045	773806
62103072002	Diversion point	1859.62	334.49	1010100	774069
62103073001	Diversion point	1864.49	333.24	1010978	772573
62103074001	Diversion point	1901.13	322.86	1017123	762560
62103075001	Diversion point	1901.13	322.86	1017123	762560
62103076001	Diversion point	1901.13	322.86	1017123	762560
62103077001	Diversion point	1901.13	322.86	1017123	762560
62103078001	Diversion point	1901.13	322.86	1017123	762560
62103079001	Diversion point	1904.67	321.17	1018689	760710
62103080310	Other secondary	1984.47	313.30	1019595	752441
62103081001	Diversion point	2034.92	295.36	1020323	738864
62103081002	Diversion point	2034.18	296.42	1020691	739965
62103082001	Diversion point	1715.40	297.31	1021402	710532
62103082002	Diversion point	1622.33	293.81	1018612	713152
62103082003	Diversion point	14.86	272.76	1022461	715046
62103082004	Diversion point	33.37	281.48	1019950	725721
62103082005	Diversion point	32.98	281.99	1019841	726470
62103082006	Diversion point	32.69	282.51	1020163	727206
62103082007	Diversion point	0.81	282.27	1018634	726578
62103082008	Diversion point	0.38	283.20	1017667	727327
62103082009	Diversion point	0.03	283.75	1017331	728153
62103082010	Diversion point	2108.16	290.46	1016757	734858
62103082011	Diversion point	2108.16	290.46	1016756	734860
62103082310	Other secondary	12.16	274.90	1020722	717564
62103083001	Diversion point	2110.34	289.13	1016648	733270
62103084001	Diversion point	2122.02	286.69	1018728	731288
62103085101	Other secondary	2033.63	297.46	1020996	740811
62103085201	Other secondary	2032.24	298.55	1021121	741433
62103086001	Diversion point	2148.45	269.67	1023131	711075

62103086002	Diversion point	2147.65	270.69	1022582	712543
62103086003	Diversion point	2147.46	270.98	1022650	712948
62103086004	Diversion point	2146.65	271.77	1022300	713925
62103086005	Diversion point	1.59	270.53	1023621	712761
62103087301	Other secondary	7.14	345.38	995489	776522
62103087401	Other secondary	0.01	344.81	995814	775754
62103087601	Other secondary	0.00	345.25	995832	776323
62103088001	Diversion point	190.16	318.04	999627	744920
62103089001	Diversion point	408.81	308.34	998951	731499
62103089002	Diversion point	407.04	309.54	998045	732989
62103090310	Other secondary	1457.81	294.32	1013778	722439
62103091310	Other secondary	1457.81	294.32	1013779	722437
62103091311	Other secondary	1457.81	294.32	1013774	722448
62103092310	Other secondary	1457.81	294.32	1013780	722435
62103092311	Other secondary	1457.81	294.32	1013767	722448
62103092312	Other secondary	1457.81	294.32	1013761	722448
62103093001	Diversion point	1714.24	296.45	1020378	710567
62103094001	Diversion point	3866.24	268.74	1023610	710014
62103094002	Diversion point	1715.40	297.31	1021403	710532
62103095310	Other secondary	3871.07	266.36	1025501	707269
62103095311	Other secondary	8.30	268.82	1022360	706092
62103095312	Other secondary	7.59	269.34	1021961	706719
62103096001	Diversion point	3870.14	267.03	1024776	707991
62103096310	Other secondary	3871.07	266.36	1025491	707278
62103097310	Other secondary	3871.07	266.36	1025498	707271
62103097311	Other secondary	3871.07	266.36	1025493	707276
62103098001	Diversion point	7.46	269.42	1021876	706811
62103099001	Diversion point	12.94	275.51	1016754	698225
62103101301	Other secondary	3.40	274.32	1022279	693531
62103102001	Diversion point	68.93	251.51	1040779	701564
62103103001	Diversion point	15.47	255.91	1042112	680662
62103104001	Diversion point	4998.84	231.02	1061219	696784
62103105001	Diversion point	5104.04	230.27	1063020	697899
62103106001	Diversion point	5108.62	230.80	1063766	698119
62103106002	Diversion point	0.03	228.08	1064975	698059
62103106301	Other secondary	0.03	228.08	1064975	698059
62103107001	Diversion point	5120.88	225.38	1067721	696031
62103107002	Diversion point	5111.25	227.93	1065201	697878
62103108001	Diversion point	3.93	225.38	1067726	696032
62103109001	Diversion point	5115.41	228.13	1066200	697583

62103111001	Diversion point	5121.41	224.36	1068713	696723
62103112001	Diversion point	5145.94	223.88	1069185	696806
62103112002	Diversion point	5121.48	224.01	1069085	696821
62103114001	Diversion point	5149.50	222.17	1070824	697684
62103114002	Diversion point	5149.50	222.17	1070823	697682
62103114301	Other secondary	5149.50	222.17	1070822	697682
62103115001	Diversion point	5149.50	222.17	1070817	697666
62103116001	Diversion point	5149.50	222.17	1070818	697668
62103117001	Diversion point	5149.50	222.17	1070819	697671
62103118001	Diversion point	5197.26	217.43	1075132	694633
62103119001	Diversion point	5197.26	217.43	1075131	694637
62103120001	Diversion point	5197.26	217.43	1075132	694656
62103121001	Diversion point	5197.26	217.43	1075131	694655
62103122001	Diversion point	5197.26	217.43	1075131	694654
62103123001	Diversion point	5198.04	216.62	1076153	694187
62103123002	Diversion point	5197.26	217.43	1075130	694645
62103124001	Diversion point	5198.08	216.51	1076278	694192
62103125001	Diversion point	5216.72	215.76	1076716	694192
62103126001	Diversion point	5217.31	215.37	1076968	693700
62103127001	Diversion point	5217.63	214.95	1077138	693193
62103128001	Diversion point	5218.30	214.30	1077806	692704
62103128002	Diversion point	5218.30	214.30	1077804	692703
62103129001	Diversion point	5218.30	214.30	1077806	692704
62103130001	Diversion point	5243.59	214.01	1077995	692363
62103131001	Diversion point	5244.60	212.98	1078014	691046
62103132001	Diversion point	5246.04	211.44	1079573	689951
62103132002	Diversion point	5245.16	211.99	1079011	690006
62103132003	Diversion point	13.13	212.24	1078692	689774
62103133001	Diversion point	5281.21	208.76	1082040	687224
62103133002	Diversion point	5268.00	209.63	1081099	688211
62103133003	Diversion point	5267.84	209.76	1081004	688372
62103134001	Diversion point	5268.69	209.11	1081673	687701
62103135001	Diversion point	5284.38	208.36	1081929	685597
62103135002	Diversion point	5282.87	208.59	1082062	685881
62103135003	Diversion point	5282.82	208.77	1082263	685954
62103135004	Diversion point	5281.38	208.23	1082728	686900
62103135005	Diversion point	12.33	208.49	1082697	687034
62103135006	Diversion point	5281.30	208.55	1082431	687023
62103136001	Diversion point	5281.64	208.10	1082805	686889
62103136002	Diversion point	12.33	208.49	1082696	687038

62103137001	Diversion point	5281.64	208.10	1082809	686885
62103138001	Diversion point	5282.25	207.66	1083103	686288
62103138002	Diversion point	5281.92	207.74	1083002	686390
62103139310	Other secondary	5284.66	204.83	1085590	684338
62103139311	Other secondary	8.69	205.39	1084263	682187
62103140001	Diversion point	5389.00	196.44	1091319	674937
62103141001	Diversion point	0.36	156.33	1128256	670308
62103142001	Diversion point	7988.74	154.19	1128757	672539
62103143001	Diversion point	8096.68	143.89	1137007	680776
62103143002	Diversion point	8074.06	145.23	1135865	679678
62103144310	Other secondary	8466.27	119.19	1161979	692476
62103145001	Diversion point	21.09	371.29	1020292	860914
62103145002	Diversion point	23.36	370.39	1021092	860415
62103145003	Diversion point	24.04	369.58	1021502	859764
62103145004	Diversion point	34.14	369.03	1022198	859314
62103145301	Other secondary	21.09	371.29	1020292	860915
62103145302	Other secondary	23.36	370.39	1021092	860416
62103145303	Other secondary	24.04	369.58	1021501	859764
62103145304	Other secondary	28.97	370.71	1022869	861258
62103145305	Other secondary	34.14	369.03	1022199	859314
62103146001	Diversion point	60.24	367.67	1022832	857571
62103147001	Diversion point	137.49	354.23	1023682	842252
62103148001	Diversion point	38.14	367.42	1032793	854155
62103148002	Diversion point	38.14	367.42	1032793	854155
62103148003	Diversion point	36.70	368.68	1032059	855299
62103148004	Diversion point	35.81	369.10	1032173	855722
62103148005	Diversion point	35.81	369.10	1032176	855724
62103148301	Other secondary	40.19	365.61	1031658	853182
62103148302	Other secondary	39.67	366.92	1032122	853856
62103148303	Other secondary	1.12	367.05	1032191	854028
62103148304	Other secondary	38.17	367.34	1032739	854031
62103148305	Other secondary	38.14	367.42	1032796	854160
62103148306	Other secondary	36.97	368.02	1032981	854958
62103148307	Other secondary	36.70	368.68	1032061	855300
62103148308	Other secondary	35.81	369.10	1032171	855722
62103148501	Return flow	38.14	367.42	1032796	854160
62103149001	Diversion point	57.25	361.65	1031029	849400
62103150001	Diversion point	73.21	359.31	1028640	847186
62103150002	Diversion point	73.11	359.50	1028760	847414
62103151001	Diversion point	79.82	357.55	1027577	844933

62103151002	Diversion point	79.63	357.75	1027712	845193
62103151003	Diversion point	73.94	358.67	1028590	846134
62103152001	Diversion point	84.91	357.04	1027403	844362
62103153001	Diversion point	235.34	352.93	1024311	840640
62103153002	Diversion point	235.21	353.24	1024106	841070
62103153003	Diversion point	0.43	353.17	1024443	840838
62103154001	Diversion point	0.65	351.78	1023480	839629
62103155001	Diversion point	237.85	351.52	1023474	839343
62103155002	Diversion point	237.82	351.76	1023560	839499
62103156001	Diversion point	241.95	349.37	1023970	836585
62103156002	Diversion point	241.88	349.50	1024068	836661
62103157001	Diversion point	266.78	347.48	1024852	834340
62103157002	Diversion point	266.52	347.72	1024810	834688
62103157003	Diversion point	266.45	347.85	1024696	834887
62103158001	Diversion point	266.52	347.72	1024828	834660
62103158501	Return flow	316.09	341.43	1025042	827594
62103158502	Return flow	305.61	343.18	1024508	828601
62103159001	Diversion point	267.40	347.40	1024837	834238
62103160001	Diversion point	268.27	346.74	1024710	833300
62103160002	Diversion point	268.05	347.03	1024625	833753
62103161001	Diversion point	14.07	350.12	1026983	836857
62103161002	Diversion point	12.19	350.59	1027089	837422
62103162001	Diversion point	2.85	345.71	1021083	830072
62103163001	Diversion point	316.34	341.12	1025153	827221
62103164001	Diversion point	322.99	337.76	1026063	823702
62103165001	Diversion point	339.95	335.86	1027094	822417
62103166001	Diversion point	351.05	332.55	1027726	818890
62103167001	Diversion point	351.06	332.50	1027727	818836
62103168001	Diversion point	385.86	329.05	1028650	815521
62103169001	Diversion point	391.58	328.22	1027885	814602
62103170001	Diversion point	393.20	327.17	1028710	813614
62103171001	Diversion point	397.23	326.44	1029565	813023
62103171002	Diversion point	396.64	326.78	1029201	813304
62103172001	Diversion point	430.88	313.66	1033652	801350
62103173001	Diversion point	433.08	311.61	1033058	798348
62103173002	Diversion point	442.14	309.99	1034113	796899
62103174001	Diversion point	102.98	333.57	1018225	815000
62103175001	Diversion point	102.98	333.57	1018227	815019
62103176001	Diversion point	3.40	343.51	1040467	850454
62103176002	Diversion point	2.77	344.11	1040001	851221

62103176003	Diversion point	2.69	344.43	1039622	851056
62103177001	Diversion point	34.54	335.98	1043013	842119
62103178001	Diversion point	55.60	334.70	1043613	840404
62103179001	Diversion point	64.11	330.12	1043589	834621
62103179310	Other secondary	63.27	331.14	1043437	835985
62103180001	Diversion point	1.79	336.07	1036519	839267
62103181001	Diversion point	45.92	324.65	1044687	828538
62103181002	Diversion point	45.64	325.23	1044101	828956
62103181003	Diversion point	44.07	325.61	1043664	829373
62103182001	Diversion point	246.68	290.19	1049949	794747
62103184001	Diversion point	3.98	320.70	1064648	832197
62103184002	Diversion point	3.61	321.08	1064335	831729
62103185001	Diversion point	1.81	322.27	1065165	838325
62103186001	Diversion point	8.48	319.41	1067545	835496
62103186002	Diversion point	8.38	319.67	1067182	835629
62103186310	Other secondary	8.54	319.28	1067615	835304
62103187001	Diversion point	8.67	318.82	1067935	834883
62103187002	Diversion point	8.64	318.95	1067915	835081
62103188001	Diversion point	64.55	314.09	1071275	829561
62103189001	Diversion point	383.88	277.27	1091866	795288
62103190001	Diversion point	407.75	272.08	1091598	789176
62103190002	Diversion point	407.34	272.45	1092090	789340
62103190003	Diversion point	407.27	272.63	1092220	789649
62103190401	Other secondary	0.13	272.77	1092323	789683
62103191001	Diversion point	187.83	271.48	1068882	790718
62103192001	Diversion point	10.08	288.07	1072369	808825
62103193001	Diversion point	3428.10	218.67	1083407	730569
62103194001	Diversion point	30.84	291.58	1019453	780306
62103194002	Diversion point	14.67	291.54	1018866	779972
62103195001	Diversion point	129.04	287.74	1022989	778251
62103196001	Diversion point	137.72	286.55	1024086	777119
62103196002	Diversion point	137.31	286.70	1023958	777275
62103197001	Diversion point	173.08	277.79	1033151	769583
62103197002	Diversion point	170.55	279.12	1031900	770498
62103197003	Diversion point	170.46	279.33	1031939	770771
62103197004	Diversion point	170.34	279.46	1031773	770853
62103198001	Diversion point	235.16	269.80	1036851	760566
62103199310	Other secondary	4.51	227.09	1076272	730800
62103200001	Diversion point	39.25	210.15	1090468	719982
62103200002	Diversion point	38.33	211.30	1089164	720713

62103201001	Diversion point	3687.12	191.52	1104403	707437
62103201002	Diversion point	3687.12	191.52	1104403	707440
62103201003	Diversion point	3686.20	192.08	1104578	708145
62103201004	Diversion point	3686.20	192.08	1104586	708150
62103201005	Diversion point	3685.78	192.49	1105013	708629
62103201006	Diversion point	3685.78	192.49	1105012	708630
62103203001	Diversion point	4098.89	179.17	1112057	700384
62103203310	Other secondary	0.06	180.07	1112566	700523
62103204001	Diversion point	4464.19	144.27	1145172	702280
62103204002	Diversion point	4463.81	144.43	1144735	702230
62103204003	Diversion point	4463.58	144.86	1144305	702027
62103205001	Diversion point	4464.28	143.92	1145442	702444
62103205002	Diversion point	4464.24	144.03	1145328	702377
62103205003	Diversion point	4463.70	144.59	1144599	702180
62103206001	Diversion point	4477.23	142.67	1147094	702418
62103206002	Diversion point	7.17	143.05	1146731	702210
62103206003	Diversion point	4469.81	143.12	1146360	702524
62103207001	Diversion point	29.30	225.94	1109305	786168
62103208310	Other secondary	0.89	213.53	1106547	769704
62103209001	Diversion point	79.31	211.14	1104368	769505
62103210001	Diversion point	146.98	207.88	1102528	765910
62103210310	Other secondary	4.29	208.14	1102294	766003
62103211310	Other secondary	155.29	206.39	1102652	763951
62103211311	Other secondary	155.29	206.39	1102650	763955
62103212001	Diversion point	3.12	205.49	1091565	751873
62103212002	Diversion point	1.87	206.60	1091535	753337
62103213001	Diversion point	0.25	156.25	1138643	721936
62103214001	Diversion point	5478.07	112.59	1171815	703554
62103215001	Diversion point	6905.55	105.17	1177047	701070
62103215002	Diversion point	6889.58	107.77	1176484	703728
62103216001	Diversion point	327.45	172.50	1147371	758442
62103216301	Other secondary	327.45	172.50	1147367	758450
62103217001	Diversion point	460.98	164.60	1154135	755172
62103217002	Diversion point	458.77	164.86	1153927	755507
62103218001	Diversion point	486.23	159.66	1156357	751680
62103219001	Diversion point	499.58	154.22	1159580	749158
62104772001	Diversion point	7.23	174.40	1143764	754384
62104772301	Other secondary	7.23	174.40	1143762	754384
62108034401	Other secondary	0.00	172.56	1147253	758451

APPENDIX B: GUADALUPE BASIN RESULTS

B.1 INTRODUCTION

The following appendix contains a table of watershed parameters for all of the control points in the Guadalupe River basin. The table includes the control point identification number, type of control point, drainage area in square miles, flowlength to outlet in miles, and the x and y coordinates of the control point location based on the TSMS Albers projection described in Chapter 3.

ID	Type	Area (mi^2)	Flowlength (mi)	X-coord.	Y-coord.
1	Stream gage	837.78	402.01	1106216	867086
2	Stream gage	1314.70	330.75	1155876	856044
3	Stream gage	1432.25	302.41	1173844	857275
4	Stream gage	1519.03	278.36	1182551	840347
5	Stream gage	129.54	278.06	1181422	839306
6	Other primary	2103.07	176.84	1245044	815594
8	Stream gage	355.31	277.26	1184093	871281
9	Stream gage	412.43	257.96	1201351	869998
10	Stream gage	838.81	208.07	1227016	835698
11	Stream gage	310.63	206.29	1231462	839520
12	Stream gage	459.79	153.74	1259823	815096
13	Stream gage	549.05	125.21	1247601	786093
14	Stream gage	4935.00	100.48	1260471	769802
15	Stream gage	5195.88	50.08	1291215	740309
16	Stream gage	493.42	51.11	1276506	732321
38	Stream gage	10122.30	15.87	1304617	708825
45	Other primary	1660.55	270.84	1186324	836693
71	Other primary	43.27	252.75	1197898	861902
72	Other primary	33.98	252.55	1195292	857921
73	Other primary	12.38	250.80	1188131	851769
74	Other primary	4.22	270.68	1185572	847215
901	Confluence	862.23	398.57	1109070	867308
902	Confluence	910.46	395.38	1111595	868969
903	Confluence	972.66	385.33	1118720	865105
904	Confluence	1049.01	380.02	1123591	866348
905	Confluence	1088.23	367.56	1128049	859469
906	Confluence	1085.94	368.97	1128264	861240
907	Confluence	1368.82	311.76	1163954	859419
908	Confluence	12.00	305.61	1170093	858240
909	Confluence	382.99	269.09	1191954	871540
910	Confluence	1434.74	301.70	1174214	857427
911	Confluence	531.20	246.15	1201186	856674
912	Confluence	538.45	243.20	1204550	856881
913	Confluence	1736.78	255.23	1192539	822006
914	Confluence	1800.80	245.22	1200165	820929
915	Confluence	1870.64	243.91	1201808	821261
916	Confluence	382.94	202.61	1231150	835731
917	Confluence	3506.00	160.89	1251414	811560

918	Confluence	5188.95	55.78	1290567	744243
919	Confluence	613.20	221.22	1216103	840704
920	Confluence	1267.17	339.23	1147175	858686
921	Confluence	1351.65	318.23	1160445	862151
922	Confluence	1450.91	297.33	1177709	856570
11803747301	Other secondary	8.30	245.28	1209647	872661
11803747302	Other secondary	7.21	246.02	1209867	873843
11803769001	Diversion point	486.35	428.53	1080393	876638
11803769301	Other secondary	486.35	428.53	1080397	876633
11803825301	Other secondary	3.39	427.97	1080880	857045
11803846301	Other secondary	8.46	427.34	1080722	859590
11803857001	Diversion point	839.01	207.79	1227083	835184
11803859001	Diversion point	813.94	213.05	1222532	836034
11803895001	Diversion point	5813.07	30.44	1296511	724283
11803895401	Other secondary	0.00	27.20	1299622	725653
11803895501	Return flow	3.44	25.55	1297737	724217
11803896001	Diversion point	3.47	430.82	1086296	879890
11803896301	Other secondary	3.47	430.82	1086294	879892
11803899301	Other secondary	1.21	290.78	1174355	871511
11803904301	Other secondary	9.86	427.92	1084471	876708
11803904302	Other secondary	9.59	428.15	1084674	877025
11803916001	Diversion point	845.05	203.97	1229290	832976
11803960001	Diversion point	11.39	329.65	1141794	880065
11803960301	Other secondary	11.39	329.65	1141793	880064
11803973001	Diversion point	1873.10	241.94	1204065	821131
11803995101	Other secondary	11.83	202.61	1231081	835690
11803995201	Other secondary	9.74	203.66	1229896	836381
11804007301	Other secondary	3.88	415.76	1095018	859653
11804020001	Diversion point	5092.99	70.31	1277896	753844
11804022101	Other secondary	584.08	229.71	1211710	846793
11804022201	Other secondary	583.15	230.78	1211680	847867
11804027001	Diversion point	420.48	255.94	1201576	867930
11804033001	Diversion point	582.58	231.87	1210954	848552
11804033002	Diversion point	581.90	232.26	1210556	849134
11804034001	Diversion point	66.33	446.44	1062307	887731
11804034002	Diversion point	66.20	446.52	1062165	888028
11804034301	Other secondary	66.33	446.44	1062304	887734
11804034302	Other secondary	66.20	446.52	1062164	888030
11804043101	Other secondary	541.64	239.86	1207522	854959
11804043201	Other secondary	541.36	240.46	1206855	855028

11804062001	Diversion point	5115.62	64.86	1282799	749723
11804075001	Diversion point	2103.32	176.17	1245374	816288
11804080001	Diversion point	582.19	232.21	1210643	849147
11804089001	Diversion point	3463.06	174.51	1245074	817495
11804106001	Diversion point	1186.63	342.50	1145889	857597
11804110001	Diversion point	586.47	227.06	1213077	845746
11804114001	Diversion point	17.22	278.63	1181245	839876
11804114501	Return flow	17.13	279.07	1180758	839875
11804182001	Diversion point	5093.58	68.66	1278793	751835
11804182002	Diversion point	5093.54	68.79	1278848	752079
11804223001	Diversion point	62.54	446.98	1062040	888632
11804223301	Other secondary	62.54	446.98	1062033	888642
11804223401	Other secondary	0.02	447.27	1061777	888761
11804230301	Other secondary	1.64	302.24	1174186	858093
11804230302	Other secondary	1.56	302.56	1174172	858556
11804230303	Other secondary	1.47	302.82	1174291	858871
11804230307	Other secondary	1.30	302.92	1174334	859076
11804230308	Other secondary	0.73	303.51	1174117	859950
11804247301	Other secondary	109.58	319.66	1152160	882187
11804298001	Diversion point	11.63	431.88	1081583	881539
11804298301	Other secondary	11.63	431.88	1081584	881536
11804302301	Other secondary	26.25	313.06	1153513	871706
11804308301	Other secondary	580.60	233.80	1209346	848242
11804318001	Diversion point	4216.27	104.44	1259707	773839
11804324301	Other secondary	41.31	57.48	1291274	746216
11804373001	Diversion point	756.96	220.63	1216595	841144
11804373002	Diversion point	143.36	221.99	1215441	840556
11804373003	Diversion point	613.16	221.37	1215922	840865
11804373004	Diversion point	612.84	222.09	1215793	841667
11804373005	Diversion point	612.78	222.36	1216143	841763
11804388301	Other secondary	4.10	275.14	1187619	875750
11804426301	Other secondary	3.86	247.14	1209244	875294
11804441001	Diversion point	5083.86	73.01	1276776	757378
11804445501	Return flow	1432.27	301.83	1174114	857395
11804486001	Diversion point	55.92	405.80	1102725	869007
11804491001	Diversion point	11.71	320.20	1158335	861888
11804491002	Diversion point	10.92	321.57	1157184	862530
11804491003	Diversion point	8.10	322.62	1156833	863123
11804491301	Other secondary	11.45	320.38	1158153	862013
11804491302	Other secondary	11.09	320.96	1157757	862542

11804491303	Other secondary	11.03	321.31	1157495	862344
11804492001	Diversion point	541.79	239.63	1207756	854663
11804492301	Other secondary	541.79	239.63	1207755	854664
11804492501	Return flow	541.79	239.63	1207756	854662
11804502001	Diversion point	582.75	231.27	1210980	847976
11804502501	Return flow	583.67	230.15	1211302	847373
11804518001	Diversion point	310.64	206.34	1231486	839477
11804539001	Diversion point	0.05	162.73	1250279	810735
11804539301	Other secondary	0.05	162.73	1250279	810735
11804569101	Other secondary	612.47	222.89	1216126	842359
11804569201	Other secondary	612.24	223.41	1215454	842644
11804586001	Diversion point	10127.73	11.11	1309071	704482
11804586401	Other secondary	0.00	10.45	1309559	703649
11804586501	Return flow	2.86	9.46	1309724	704124
11804590001	Diversion point	982.88	380.96	1123065	865593
11804597101	Other secondary	784.12	216.55	1219664	837784
11804597201	Other secondary	783.78	217.04	1218901	838283
11804598101	Other secondary	841.53	400.96	1107223	867539
11804598201	Other secondary	839.62	401.23	1106853	867597
11804607001	Diversion point	1336.16	318.50	1160662	861820
11805006101	Other secondary	5031.36	84.62	1273765	765385
11805006201	Other secondary	5030.83	85.35	1273895	766504
11805012001	Diversion point	2.45	18.56	1301113	709252
11805012501	Return flow	2.51	18.30	1301399	708984
11805036001	Diversion point	1325.32	183.99	1239361	822901
11805036401	Other secondary	0.00	184.34	1239223	822658
11805037101	Other secondary	861.64	201.19	1231379	832370
11805037201	Other secondary	845.14	203.65	1229601	833189
11805038001	Diversion point	1301.96	192.17	1235680	826202
11805060001	Diversion point	11.03	440.76	1068738	884389
11805060301	Other secondary	11.03	440.71	1068727	884392
11805092001	Diversion point	583.15	230.72	1211619	847894
11805107001	Diversion point	2.63	403.43	1105231	865862
11805107002	Diversion point	0.05	405.58	1106132	863662
11805107301	Other secondary	0.05	405.58	1106130	863661
11805121001	Diversion point	58.07	239.99	1196675	844658
11805121401	Other secondary	0.00	240.04	1196662	844578
11805122001	Diversion point	641.99	416.12	1091300	864725
11805122401	Other secondary	0.10	416.60	1091424	864079
11805125001	Diversion point	42.28	344.41	1142961	862454

11805208001	Diversion point	48.13	414.07	1093940	863455
11805234001	Diversion point	814.39	212.30	1223321	836352
11805234002	Diversion point	815.08	211.42	1224102	835389
11805234003	Diversion point	815.09	211.24	1224230	835424
11805234004	Diversion point	817.45	210.37	1225044	835609
11805234005	Diversion point	838.04	209.34	1225932	835962
11805240001	Diversion point	783.77	217.04	1218886	838292
11805240401	Other secondary	0.01	217.99	1218036	837778
11805267001	Diversion point	461.15	152.70	1259720	813880
11805267301	Other secondary	461.15	152.70	1259720	813879
11805294301	Other secondary	26.34	92.92	1242703	760109
11805294302	Other secondary	26.38	92.79	1242755	759945
11805315301	Other secondary	5.86	431.51	1081933	881358
11805315302	Other secondary	5.86	431.51	1081942	881353
11805315303	Other secondary	5.44	431.86	1082465	881457
11805315304	Other secondary	5.38	431.97	1082488	881617
11805315305	Other secondary	5.32	432.33	1082855	881784
11805321001	Diversion point	23.47	382.53	1124629	869419
11805322301	Other secondary	11.73	440.11	1068470	883578
11805331001	Diversion point	91.25	444.77	1061615	874851
11805331301	Other secondary	91.25	444.77	1061615	874851
11805348001	Diversion point	128.39	449.70	1055669	876753
11805352001	Diversion point	95.32	443.58	1062717	875676
11805371101	Other secondary	0.16	292.31	1173113	881567
11805371201	Other secondary	0.03	292.49	1173013	881869
11805376001	Diversion point	42.45	56.59	1290983	745053
11805376301	Other secondary	42.45	56.59	1290979	745051
11805376302	Other secondary	42.59	56.28	1290432	744932
11805381001	Diversion point	10146.60	7.61	1312198	700695
11805381401	Other secondary	0.00	7.72	1312215	701033
11805394001	Diversion point	486.35	428.53	1080391	876641
11805401301	Other secondary	15.46	432.97	1075124	868598
11805401302	Other secondary	15.40	433.05	1075082	868777
11805402301	Other secondary	25.29	431.70	1075327	867434
11805424301	Other secondary	4.34	59.13	1291241	748546
11805426001	Diversion point	67.24	300.11	1167065	874992
11805444001	Diversion point	451.49	431.59	1076512	878284
11805466001	Diversion point	5190.45	53.38	1289968	742394
11805466401	Other secondary	0.00	52.75	1291192	742698
11805474001	Diversion point	923.98	387.82	1116742	866863

11805474002	Diversion point	930.22	385.92	1118019	865709
11805479001	Diversion point	715.34	410.56	1097665	863853
11805489001	Diversion point	2.04	19.24	1300179	709577
11805489002	Diversion point	0.83	21.83	1299003	710384
11805489101	Other secondary	9.24	21.08	1298771	711394
11805489201	Other secondary	58.57	20.85	1298991	711688
11805489401	Other secondary	0.00	22.13	1299845	710789
11805490001	Diversion point	923.22	388.54	1116060	866428
11805495301	Other secondary	66.38	450.45	1058193	871039
11805501001	Diversion point	5.77	402.75	1108549	872068
11805521001	Diversion point	484.92	429.10	1079788	877300
11805528101	Other secondary	842.10	400.12	1107926	866475
11805528201	Other secondary	841.76	400.63	1107513	867111
11805531001	Diversion point	561.77	420.21	1087360	868116
11805534001	Diversion point	923.31	388.36	1116158	866492
11805536001	Diversion point	709.77	411.18	1096832	864337
11805541001	Diversion point	188.13	441.87	1063127	879530
11805545001	Diversion point	1.78	302.67	1166493	883647
11805556001	Diversion point	122.73	316.28	1156182	881160
61801930001	Diversion point	20.99	458.70	1047429	876945
61801930301	Other secondary	20.99	458.70	1047429	876946
61801932001	Diversion point	117.01	454.38	1051201	877465
61801932301	Other secondary	117.01	454.38	1051199	877463
61801932501	Return flow	117.02	454.44	1051231	877493
61801934001	Diversion point	2.96	450.78	1054391	876938
61801934302	Other secondary	31.45	450.31	1054869	878351
61801935001	Diversion point	128.44	449.49	1055954	876810
61801935005	Diversion point	2.84	449.88	1056177	876203
61801936001	Diversion point	128.65	449.03	1056360	877150
61801936002	Diversion point	128.51	449.32	1056171	876971
61801936003	Diversion point	2.99	449.67	1056353	876623
61801936004	Diversion point	2.94	449.83	1056264	876427
61801936006	Diversion point	2.36	450.21	1056158	875801
61801936007	Diversion point	2.33	450.37	1056066	875638
61801937301	Other secondary	31.62	449.87	1055283	878045
61801937303	Other secondary	31.43	450.36	1054716	878347
61801938001	Diversion point	32.14	448.92	1056354	877364
61801938002	Diversion point	128.66	449.03	1056424	877205
61801939001	Diversion point	1.55	449.26	1056459	878003
61801939301	Other secondary	1.55	449.26	1056459	878004

61801940001	Diversion point	1.67	449.05	1056689	877674
61801940002	Diversion point	162.59	448.63	1056749	877332
61801940301	Return flow	1.67	449.05	1056691	877682
61801941301	Other secondary	38.56	428.44	1079127	866450
61801943001	Diversion point	169.94	445.61	1060392	877677
61801945001	Diversion point	173.33	443.12	1061961	879061
61801946001	Diversion point	173.37	443.12	1061978	879105
61801947001	Diversion point	173.39	443.06	1061997	879130
61801948001	Diversion point	0.50	443.24	1061604	879624
61801948002	Diversion point	0.32	443.40	1061447	879528
61801948301	Other secondary	0.50	443.24	1061605	879624
61801948302	Other secondary	0.32	443.40	1061443	879524
61801949001	Diversion point	8.73	445.84	1061307	881755
61801949002	Diversion point	8.64	446.05	1061075	881709
61801950001	Diversion point	10.58	444.83	1061391	880650
61801950002	Diversion point	10.71	444.70	1061691	880451
61801950301	Other secondary	10.58	444.83	1061388	880651
61801950302	Other secondary	10.71	444.70	1061690	880451
61801952301	Other secondary	1.63	318.84	1159954	862513
61801952302	Other secondary	1.56	318.97	1159866	862718
61801952303	Other secondary	1.47	319.02	1159864	862814
61801952304	Other secondary	1.47	319.08	1159869	862922
61801953001	Diversion point	188.13	441.87	1063118	879531
61801954001	Diversion point	1.87	313.96	1162198	853539
61801954002	Diversion point	0.25	316.83	1161152	854870
61801954301	Other secondary	1.87	313.96	1162198	853539
61801954302	Other secondary	0.25	316.83	1161153	854871
61801955101	Other secondary	1.41	315.17	1162391	856293
61801955201	Other secondary	1.00	315.38	1162448	855950
61801955301	Other secondary	1.00	315.38	1162449	855957
61801956001	Diversion point	66.71	449.95	1059022	870662
61801956301	Other secondary	66.71	449.95	1059021	870665
61801957301	Other secondary	73.09	449.35	1059585	870685
61801958001	Diversion point	9.24	449.68	1060962	869895
61801958301	Other secondary	9.24	449.68	1060956	869886
61801961001	Diversion point	90.16	445.52	1061749	874004
61801963001	Diversion point	97.22	441.12	1064005	878110
61801963301	Other secondary	97.22	441.12	1064005	878112
61801963302	Other secondary	97.28	440.85	1064236	878347
61801964001	Diversion point	1.24	445.87	1064385	872455

61801964002	Diversion point	1.32	445.77	1064376	872626
61801964003	Diversion point	0.99	446.11	1065579	872663
61801964301	Other secondary	1.24	445.87	1064384	872460
61801964302	Other secondary	0.99	446.11	1065577	872672
61801967001	Diversion point	293.84	439.32	1066077	877944
61801967301	Other secondary	0.12	439.92	1066007	877288
61801968001	Diversion point	295.93	438.84	1066669	878142
61801968002	Diversion point	299.06	438.12	1067597	878333
61801968003	Diversion point	5.22	439.04	1067850	876341
61801968004	Diversion point	5.21	439.10	1067772	876305
61801968005	Diversion point	4.70	439.98	1067511	875296
61801968006	Diversion point	3.88	440.14	1067636	875199
61801969002	Diversion point	6.44	438.21	1068086	877439
61801969301	Other secondary	6.44	438.21	1068085	877435
61801969501	Return flow	299.25	437.75	1068097	878156
61801970001	Diversion point	306.97	436.90	1069061	878298
61801970002	Diversion point	307.67	436.58	1069396	878527
61801971301	Other secondary	310.67	435.01	1071616	878410
61801972001	Diversion point	1.69	448.02	1061050	889760
61801973001	Diversion point	3.31	447.18	1061598	887909
61801973301	Other secondary	3.31	447.18	1061593	887907
61801974001	Diversion point	3.40	446.91	1061746	888191
61801974301	Other secondary	3.40	446.91	1061750	888192
61801974302	Other secondary	3.40	446.96	1061818	888232
61801974303	Other secondary	3.41	446.78	1062033	888235
61801974304	Other secondary	66.20	446.52	1062166	888027
61801975001	Diversion point	0.21	446.80	1062969	889072
61801975002	Diversion point	8.42	446.36	1062953	888546
61801975301	Other secondary	0.21	446.80	1062966	889070
61801975401	Other secondary	0.00	446.13	1062773	887866
61801975501	Return flow	8.66	445.86	1063049	887826
61801976001	Diversion point	8.42	446.36	1062952	888547
61801976301	Other secondary	8.42	446.36	1062953	888544
61801977001	Diversion point	75.21	445.62	1063284	887634
61801977002	Diversion point	75.28	445.47	1063508	887509
61801977301	Other secondary	75.21	445.62	1063294	887632
61801978001	Diversion point	76.24	444.99	1063671	886838
61801979001	Diversion point	2.92	445.48	1063122	886385
61801980001	Diversion point	81.01	443.66	1065288	886222
61801981001	Diversion point	81.14	443.40	1065499	885822

61801981002	Diversion point	81.15	443.35	1065499	885736
61801981003	Diversion point	81.20	443.25	1065532	885627
61801981004	Diversion point	92.47	442.90	1065557	885203
61801981005	Diversion point	94.70	442.72	1065734	884958
61801982001	Diversion point	95.37	442.07	1066301	884380
61801982301	Other secondary	95.37	442.07	1066302	884378
61801983001	Diversion point	98.68	441.50	1066965	883976
61801983002	Diversion point	98.90	441.39	1067169	883940
61801984001	Diversion point	99.09	441.01	1067365	883506
61801985001	Diversion point	99.09	441.01	1067370	883512
61801987001	Diversion point	99.12	440.80	1067307	883378
61801988001	Diversion point	8.21	442.79	1068751	886922
61801988002	Diversion point	8.82	442.06	1068554	886017
61801988003	Diversion point	9.05	441.80	1068882	885656
61801990001	Diversion point	113.36	438.83	1068330	882005
61801991001	Diversion point	4.52	438.72	1072498	883357
61801991301	Other secondary	4.52	438.72	1072498	883353
61801992001	Diversion point	124.59	436.05	1071398	880435
61801993001	Diversion point	124.64	436.16	1071385	880318
61801993301	Other secondary	124.61	436.05	1071383	880397
61801994001	Diversion point	448.23	433.25	1074116	878208
61801995001	Diversion point	19.06	431.11	1077072	878529
61801995002	Diversion point	18.85	431.27	1077202	878619
61801995301	Other secondary	19.06	431.16	1077071	878534
61801995302	Other secondary	18.85	431.18	1077205	878618
61801996001	Diversion point	512.13	426.83	1082633	875702
61801996002	Diversion point	512.13	426.83	1082634	875702
61801996003	Diversion point	512.13	426.83	1082634	875702
61801996004	Diversion point	486.53	428.40	1080591	876406
61801996301	Other secondary	512.13	426.83	1082636	875700
61801997001	Diversion point	485.15	429.00	1080048	877063
61801997501	Return flow	486.26	428.66	1080198	876773
61801998001	Diversion point	11.11	431.96	1081463	881866
61801998002	Diversion point	11.11	431.96	1081465	881872
61801998003	Diversion point	11.11	431.96	1081465	881872
61801998004	Diversion point	11.16	431.90	1081434	881778
61801998005	Diversion point	11.18	431.85	1081411	881706
61801998301	Other secondary	11.11	431.96	1081464	881868
61801999301	Other secondary	0.42	428.33	1081084	875489
61802000001	Diversion point	525.62	424.67	1084147	873110

61802000002	Diversion point	9.70	425.29	1083339	872791
61802000301	Other secondary	9.70	425.29	1083335	872792
61802001001	Diversion point	537.54	423.24	1085428	871423
61802002001	Diversion point	552.13	422.55	1085980	870561
61802003001	Diversion point	551.24	422.91	1085620	871031
61802004301	Other secondary	552.23	422.44	1086002	870379
61802005001	Diversion point	562.27	419.78	1087410	867385
61802005002	Diversion point	562.69	419.54	1087487	867093
61802006001	Diversion point	564.34	418.83	1088312	866136
61802006002	Diversion point	564.37	418.70	1088472	865993
61802006003	Diversion point	562.85	419.28	1087667	866706
61802006004	Diversion point	552.98	421.49	1085902	869003
61802006301	Other secondary	564.34	418.83	1088313	866135
61802006401	Other secondary	0.00	418.85	1088212	866260
61802007001	Diversion point	1.06	434.74	1073483	870088
61802007002	Diversion point	1.90	434.38	1074004	869715
61802007003	Diversion point	2.01	433.86	1074084	869152
61802007301	Other secondary	1.06	434.74	1073484	870087
61802008001	Diversion point	15.46	432.97	1075124	868591
61802008301	Other secondary	15.46	432.97	1075123	868594
61802009001	Diversion point	7.05	434.73	1072945	866185
61802009301	Other secondary	7.05	434.73	1072943	866183
61802010001	Diversion point	7.18	434.40	1073178	866449
61802010301	Other secondary	7.19	434.40	1073188	866476
61802011001	Diversion point	32.80	430.40	1076497	866250
61802011002	Diversion point	32.86	430.13	1076792	866418
61802011003	Diversion point	32.95	429.96	1076959	866519
61802011004	Diversion point	2.85	429.84	1077378	866198
61802011301	Other secondary	2.85	429.84	1077381	866202
61802012001	Diversion point	38.91	428.15	1079449	866419
61802012301	Other secondary	38.91	428.15	1079450	866418
61802013001	Diversion point	0.35	427.50	1079718	868509
61802014001	Diversion point	70.47	418.39	1088687	865537
61802014002	Diversion point	70.28	418.68	1088257	865496
61802015001	Diversion point	640.04	417.40	1089728	864894
61802016001	Diversion point	643.16	415.67	1091926	864876
61802017301	Other secondary	643.83	415.56	1092609	864859
61802018001	Diversion point	6.51	414.74	1093012	865060
61802020001	Diversion point	650.86	413.90	1093939	864566
61802021001	Diversion point	651.01	413.69	1094113	864237

61802021401	Other secondary	0.00	414.62	1093178	863525
61802022001	Diversion point	650.83	413.95	1093924	864601
61802022401	Other secondary	0.00	415.20	1094073	866064
61802022402	Other secondary	0.00	415.11	1093813	865871
61802023001	Diversion point	651.07	413.51	1094433	864227
61802024001	Diversion point	651.07	413.40	1094488	864237
61802024002	Diversion point	651.20	413.29	1094649	864265
61802025001	Diversion point	651.21	413.29	1094692	864273
61802026001	Diversion point	652.81	413.08	1095095	864401
61802026002	Diversion point	652.88	412.84	1095337	864275
61802027001	Diversion point	1.63	429.43	1079631	856785
61802028002	Diversion point	1.66	429.17	1079836	856597
61802028301	Other secondary	3.05	431.16	1077089	858031
61802029001	Diversion point	2.43	424.44	1084022	857920
61802029002	Diversion point	25.14	422.60	1085923	858731
61802029301	Other secondary	2.43	424.44	1084019	857916
61802030001	Diversion point	31.14	421.12	1087603	859588
61802030002	Diversion point	3.09	421.01	1088001	859523
61802030301	Other secondary	3.09	421.01	1088002	859521
61802031001	Diversion point	740.40	408.80	1100000	863877
61802031101	Other secondary	740.40	408.80	1099999	863877
61802031201	Other secondary	741.71	408.64	1100196	863869
61802032001	Diversion point	742.23	408.32	1100879	863890
61802033001	Diversion point	753.62	406.47	1102570	864941
61802034001	Diversion point	760.56	405.11	1103789	865009
61802034002	Diversion point	760.64	405.04	1103963	864917
61802035001	Diversion point	761.56	403.83	1104543	865988
61802036001	Diversion point	764.50	403.43	1105277	865875
61802036002	Diversion point	0.05	405.58	1106131	863662
61802036301	Other secondary	0.05	405.58	1106130	863662
61802037001	Diversion point	9.10	414.30	1096616	877635
61802037002	Diversion point	9.67	414.10	1096730	877153
61802038001	Diversion point	27.52	411.47	1098222	874074
61802039001	Diversion point	28.51	410.09	1098764	872549
61802040001	Diversion point	38.38	409.39	1099432	871973
61802041001	Diversion point	55.89	405.75	1102645	869079
61802041101	Other secondary	71.49	404.24	1103857	867888
61802041201	Other secondary	71.12	404.40	1103943	868103
61802042001	Diversion point	56.02	405.35	1103264	869045
61802042002	Diversion point	70.98	404.92	1103594	868647

61802043001	Diversion point	71.00	404.92	1103630	868607
61802044001	Diversion point	841.54	401.02	1107266	867507
61802044301	Other secondary	841.54	401.02	1107264	867509
61802045001	Diversion point	841.75	400.63	1107499	867156
61802046001	Diversion point	852.46	398.84	1109025	866941
61802047001	Diversion point	865.60	395.70	1111390	868593
61802048001	Diversion point	43.65	396.04	1111429	869812
61802048002	Diversion point	44.65	395.38	1111559	868974
61802048301	Other secondary	43.65	396.04	1111427	869805
61802049001	Diversion point	910.60	394.98	1111929	869321
61802050001	Diversion point	911.38	394.08	1112619	868505
61802051101	Other secondary	40.18	387.81	1117378	863437
61802051201	Other secondary	41.39	386.34	1118033	864694
61802051301	Other secondary	40.69	386.93	1117525	864394
61802052001	Diversion point	975.59	382.68	1120833	865958
61802052002	Diversion point	977.65	382.17	1121426	865972
61802053001	Diversion point	977.83	381.96	1121853	866046
61802054001	Diversion point	982.82	381.01	1122963	865549
61802056001	Diversion point	3.48	387.29	1126310	875785
61802056301	Other secondary	3.48	387.29	1126309	875799
61802057001	Diversion point	2.48	385.88	1125027	873971
61802057301	Other secondary	2.48	385.88	1125031	873967
61802058001	Diversion point	1052.55	376.37	1126969	866710
61802058002	Diversion point	1052.58	376.09	1127223	866562
61802059001	Diversion point	1060.32	375.88	1127489	866544
61802060001	Diversion point	1052.51	376.45	1126852	866832
61802060002	Diversion point	1061.09	375.44	1128044	866256
61802060003	Diversion point	1061.31	374.51	1127138	865889
61802061001	Diversion point	1067.00	371.72	1127924	863537
61802062001	Diversion point	5.34	375.85	1121579	860024
61802062301	Other secondary	5.34	375.85	1121577	860023
61802063001	Diversion point	1088.05	367.95	1127701	859904
61802064001	Diversion point	6.12	372.32	1123679	856632
61802064002	Diversion point	6.14	372.22	1123763	856741
61802064003	Diversion point	8.97	371.60	1124221	857326
61802064004	Diversion point	9.00	371.66	1124256	857402
61802064301	Other secondary	8.97	371.60	1124222	857330
61802065001	Diversion point	14.30	368.07	1127822	859082
61802065002	Diversion point	13.50	368.30	1127551	858869
61802066001	Diversion point	14.30	367.94	1127868	859081

61802067001	Diversion point	1106.43	365.25	1130078	860047
61802067002	Diversion point	1106.50	365.09	1130273	860045
61802067003	Diversion point	1106.60	364.87	1130638	860057
61802067401	Other secondary	0.00	365.30	1130327	860195
61802069001	Diversion point	18.73	342.17	1146243	861705
61802069301	Other secondary	18.97	341.80	1146112	861167
61802070001	Diversion point	67.77	340.39	1146046	859519
61802070002	Diversion point	68.10	340.00	1146219	859082
61802070003	Diversion point	69.03	339.44	1146738	858854
61802070004	Diversion point	1267.19	339.02	1147261	858701
61802070005	Diversion point	1267.43	338.91	1147434	858695
61802071001	Diversion point	1267.58	338.53	1147791	858951
61802072001	Diversion point	1336.15	318.61	1160719	861761
61802072002	Diversion point	1351.65	318.18	1160448	862161
61802072003	Diversion point	1358.44	317.37	1161392	862564
61802073301	Other secondary	0.77	325.75	1154182	865512
61802073302	Other secondary	0.88	325.64	1154008	865472
61802074001	Diversion point	1432.27	302.12	1174030	857362
61802074301	Other secondary	1432.27	302.12	1174029	857361
61802437301	Other secondary	117.38	453.70	1052231	877187
61802438001	Diversion point	124.55	451.45	1053485	877687
61802438301	Other secondary	124.33	451.88	1053331	877288
61802439001	Diversion point	167.21	447.67	1058010	877341
61802439002	Diversion point	167.21	447.67	1058012	877340
61802439301	Other secondary	167.21	447.67	1058014	877339
61802440001	Diversion point	168.53	446.15	1059512	878157
61802441001	Diversion point	172.19	444.32	1061321	877662
61802441002	Diversion point	172.66	444.11	1061329	877933
61802441003	Diversion point	172.90	443.79	1061703	878184
61802442001	Diversion point	12.68	443.77	1062445	880996
61802442002	Diversion point	12.61	444.06	1062196	880944
61802442301	Other secondary	12.68	443.77	1062449	880994
61802442302	Other secondary	12.61	444.06	1062195	880936
61802443001	Diversion point	13.20	442.71	1062236	879774
61802443301	Other secondary	187.33	442.45	1062363	879585
61802444001	Diversion point	49.01	455.41	1053636	868335
61802444301	Diversion point	49.01	455.41	1053634	868336
61802444302	Other secondary	40.99	456.97	1053640	867044
61802445001	Diversion point	75.28	447.77	1060560	871732
61802445002	Diversion point	11.29	447.83	1060542	871635

61802445003	Diversion point	10.42	447.94	1060454	871545
61802445004	Diversion point	86.63	447.48	1060886	871732
61802445301	Other secondary	86.63	447.48	1060901	871734
61802446001	Diversion point	88.02	446.24	1061350	873198
61802446002	Diversion point	88.07	446.19	1061346	873264
61802447001	Diversion point	97.06	441.39	1063854	877885
61802447002	Diversion point	97.06	441.39	1063853	877883
61802447003	Diversion point	97.06	441.39	1063851	877881
61802447301	Other secondary	97.06	441.39	1063849	877879
61802448001	Diversion point	4.44	442.94	1064191	875121
61802449001	Diversion point	451.49	431.59	1076505	878281
61802450001	Diversion point	650.78	414.16	1093813	864794
61803815001	Diversion point	1438.53	298.60	1176891	856620
61803816001	Diversion point	1448.78	297.33	1177717	856591
61803816301	Other secondary	2.12	297.41	1177839	856512
61803816302	Other secondary	2.11	297.41	1177916	856483
61803816303	Other secondary	2.10	297.49	1178002	856582
61803816304	Other secondary	2.12	297.41	1177837	856513
61803816501	Return flow	1450.91	297.33	1177706	856566
61803817001	Diversion point	1454.72	296.95	1177443	856091
61803818301	Other secondary	1496.42	284.51	1179361	845822
61803819001	Diversion point	1516.90	280.63	1182918	842832
61803820001	Diversion point	1519.89	277.68	1182820	839576
61803821001	Diversion point	1519.92	277.61	1182735	839517
61803822001	Diversion point	1520.17	277.21	1182332	839239
61803823001	Diversion point	16.00	280.46	1180885	840922
61803824001	Diversion point	17.74	278.94	1180426	839319
61803824002	Diversion point	17.74	278.94	1180426	839318
61803824003	Diversion point	1518.25	278.69	1182143	840588
61803824004	Diversion point	17.74	278.94	1180425	839321
61803824005	Diversion point	17.03	279.52	1180185	839941
61803824301	Other secondary	17.74	278.94	1180427	839316
61803824501	Return flow	17.81	278.75	1180570	839281
61803825301	Other secondary	0.37	291.86	1170854	829769
61803825302	Other secondary	0.09	290.31	1171885	830666
61803826001	Diversion point	17.24	278.63	1181258	839839
61803826401	Other secondary	0.00	278.79	1181088	839779
61803827301	Other secondary	129.49	278.14	1181332	839425
61803828001	Diversion point	129.83	277.43	1181745	838771
61803828002	Diversion point	129.79	277.51	1181658	838909

61803828003	Diversion point	129.63	277.66	1181732	839047
61803828301	Other secondary	129.63	277.66	1181730	839045
61803829001	Diversion point	1658.12	274.04	1184501	837094
61803829002	Diversion point	1650.78	276.41	1182889	838364
61803829301	Other secondary	1650.78	276.41	1182888	838366
61803830001	Diversion point	1658.12	274.04	1184501	837095
61803830002	Diversion point	1650.78	276.41	1182889	838364
61803830301	Other secondary	1650.78	276.41	1182889	838364
61803831001	Diversion point	1665.28	268.21	1186894	833583
61803832001	Diversion point	1665.28	268.21	1186894	833583
61803833001	Diversion point	1665.28	268.21	1186894	833583
61803834001	Diversion point	1665.28	268.21	1186894	833583
61803834002	Diversion point	1665.28	268.21	1186894	833583
61803835001	Diversion point	14.72	258.92	1189816	825593
61803836001	Diversion point	1711.27	258.76	1189890	825316
61803836501	Return flow	1711.27	258.76	1189887	825280
61803837001	Diversion point	1717.50	258.09	1190519	824528
61803837002	Diversion point	1717.45	258.22	1190376	824625
61803837003	Diversion point	1711.39	258.42	1190165	824824
61803838001	Diversion point	0.95	255.71	1192190	821797
61803838002	Diversion point	0.94	255.76	1192178	821771
61803838301	Other secondary	0.11	256.08	1191931	821429
61803839001	Diversion point	1737.23	254.46	1193565	821994
61803839002	Diversion point	1737.23	254.46	1193564	821994
61803839003	Diversion point	1737.23	254.46	1193565	821994
61803839301	Other secondary	1737.23	254.46	1193564	821994
61803840001	Diversion point	28.63	257.28	1195690	835732
61803840002	Diversion point	28.45	257.82	1195200	835554
61803841001	Diversion point	60.61	248.30	1199614	826848
61803841002	Diversion point	59.68	248.53	1199246	826952
61803841401	Other secondary	0.00	248.93	1198862	826816
61803842001	Diversion point	69.27	244.02	1201784	821480
61803843001	Diversion point	1883.32	239.35	1206251	821050
61803844001	Diversion point	1968.60	224.48	1216273	820339
61803845301	Other secondary	2068.26	198.06	1233603	816934
61803846001	Diversion point	3468.60	173.30	1246322	817345
61803846002	Diversion point	3468.60	173.30	1246322	817344
61803846301	Other secondary	3468.60	173.30	1246322	817343
61803846501	Return flow	3468.60	173.30	1246322	817345
61803847001	Diversion point	3474.94	167.56	1249645	815849

61803847002	Diversion point	3474.38	168.55	1249070	817173
61803848001	Diversion point	3492.03	162.58	1251657	813181
61803848002	Diversion point	3510.49	159.22	1252989	812327
61803848301	Other secondary	3492.03	162.52	1251782	813079
61803848302	Other secondary	3510.49	159.40	1253350	812264
61803849301	Other secondary	0.90	192.74	1261185	858989
61803850001	Diversion point	4074.25	131.21	1259936	793848
61803850002	Diversion point	4074.58	130.72	1259344	794004
61803850003	Diversion point	4106.60	128.27	1259055	793601
61803851001	Diversion point	4135.99	119.03	1260267	786461
61803852001	Diversion point	4207.08	110.11	1260766	779259
61803853501	Return flow	4213.19	107.11	1261231	776948
61803854001	Diversion point	4928.17	103.19	1259568	772338
61803855001	Diversion point	4928.21	103.00	1259556	772014
61803856001	Diversion point	4928.30	102.47	1259347	771333
61803856002	Diversion point	4928.27	102.79	1259559	771672
61803858001	Diversion point	5092.99	70.31	1277900	753843
61803858002	Diversion point	5089.59	71.05	1277091	754673
61803858003	Diversion point	5086.43	71.44	1276795	755179
61803858004	Diversion point	5085.17	71.92	1276703	755850
61803858005	Diversion point	5083.93	72.66	1276797	756987
61803859001	Diversion point	5093.70	68.16	1278889	751099
61803859401	Other secondary	0.00	68.16	1279083	751108
61803860001	Diversion point	5781.05	34.46	1294094	728232
61803860401	Other secondary	0.00	34.08	1294369	727926
61803860501	Return flow	30.14	33.60	1295134	728316
61803861001	Diversion point	5812.64	31.59	1296124	725896
61803861401	Other secondary	0.00	32.78	1297862	726921
61803862001	Diversion point	5812.76	31.07	1296557	725073
61803863001	Diversion point	5874.47	21.91	1302216	715500
61803863002	Diversion point	5870.77	25.66	1298861	718896
61803865001	Diversion point	48.32	249.71	1199160	860050
61803865002	Diversion point	48.32	249.71	1199162	860057
61803865003	Diversion point	48.32	249.71	1199160	860049
61803865004	Diversion point	48.32	249.71	1199161	860053
61803865301	Other secondary	48.32	249.71	1199160	860049
61803865501	Return flow	48.32	249.71	1199160	860045
61803865502	Return flow	48.32	249.71	1199159	860041
61803866001	Diversion point	48.97	249.49	1199131	859769
61803866002	Diversion point	49.49	249.42	1199042	859680

61803866401	Other secondary	0.00	249.66	1198963	859892
61803866501	Return flow	86.86	248.84	1199312	858903
61803867301	Other secondary	87.14	248.90	1199319	858780
61803868001	Diversion point	87.73	248.28	1199570	857776
61803868301	Other secondary	87.23	248.41	1199467	858304
61803869001	Diversion point	92.46	247.89	1199734	857681
61803869401	Other secondary	0.00	248.04	1199348	857038
61803870001	Diversion point	14.69	337.99	1132517	882823
61803870301	Other secondary	14.69	337.99	1132519	882820
61803871001	Diversion point	3.97	331.17	1139267	883090
61803871002	Diversion point	4.06	330.85	1139440	882657
61803871301	Other secondary	3.97	331.17	1139269	883089
61803871302	Other secondary	4.06	330.85	1139443	882654
61803872001	Diversion point	51.50	328.67	1141285	882785
61803872002	Diversion point	52.02	328.13	1142035	882383
61803872003	Diversion point	50.38	329.29	1140824	882485
61803872301	Other secondary	50.38	329.29	1140823	882488
61803872302	Other secondary	52.02	328.13	1142037	882385
61803873001	Diversion point	51.50	328.67	1141280	882791
61803873002	Diversion point	52.02	328.13	1142041	882388
61803873301	Other secondary	52.02	328.13	1142033	882381
61803874001	Diversion point	11.39	329.65	1141794	880066
61803874002	Diversion point	11.56	329.32	1142067	880342
61803875001	Diversion point	2.86	329.15	1143593	886408
61803875002	Diversion point	2.52	329.59	1143385	887023
61803875301	Other secondary	2.52	329.59	1143386	887019
61803876301	Other secondary	94.10	323.30	1147965	882587
61803877001	Diversion point	103.83	320.83	1150973	881797
61803877301	Other secondary	103.61	321.37	1150534	882256
61803877302	Other secondary	103.83	320.83	1150976	881794
61803878301	Other secondary	108.18	320.44	1151548	881564
61803878302	Other secondary	109.42	319.85	1151999	882014
61803879301	Other secondary	110.56	318.95	1152855	882115
61803880301	Other secondary	295.37	285.39	1176374	866933
61803881001	Diversion point	295.96	284.63	1177101	867162
61803882001	Diversion point	0.48	285.48	1176562	871736
61803882002	Diversion point	0.79	285.11	1176579	871245
61803882003	Diversion point	0.94	285.09	1176669	871076
61803882004	Diversion point	1.50	284.27	1177497	870151
61803882005	Diversion point	1.51	284.27	1177479	870071

61803882301	Other secondary	0.48	285.48	1176561	871732
61803882302	Other secondary	0.79	285.11	1176579	871247
61803882303	Other secondary	0.94	285.09	1176666	871079
61803882304	Other secondary	1.50	284.27	1177496	870155
61803883301	Other secondary	7.27	287.61	1176380	878234
61803883302	Other secondary	1.94	285.25	1178233	876689
61803883303	Other secondary	1.83	281.57	1181324	874431
61803883304	Other secondary	31.22	281.55	1181241	874206
61803883305	Other secondary	33.15	281.31	1181461	874172
61803884001	Diversion point	366.67	273.32	1188420	870385
61803884401	Other secondary	0.00	273.10	1188558	870978
61803884402	Other secondary	0.00	273.76	1188359	870969
61803886001	Diversion point	434.62	249.18	1202403	859977
61803886401	Other secondary	0.00	245.67	1202785	859495
61803886402	Other secondary	0.00	245.72	1202727	859573
61803887001	Diversion point	531.47	245.57	1201977	856277
61803887002	Diversion point	541.79	239.63	1207755	854664
61803887003	Diversion point	531.55	245.33	1202353	856186
61803887301	Other secondary	531.47	245.57	1201982	856276
61803888001	Diversion point	531.85	244.80	1202923	856468
61803888002	Diversion point	531.94	244.50	1203365	856380
61803888003	Diversion point	531.96	244.40	1203528	856373
61803888004	Diversion point	532.03	244.07	1203669	856754
61803888005	Diversion point	532.53	243.70	1203997	857055
61803889001	Diversion point	532.53	243.70	1203974	857051
61803889002	Diversion point	532.51	243.75	1203847	857042
61803890001	Diversion point	582.60	231.82	1211133	848489
61803891001	Diversion point	598.53	225.55	1214248	845065
61803891002	Diversion point	598.30	225.97	1214287	845545
61803892301	Other secondary	8.27	242.66	1194690	847360
61803893301	Other secondary	4.86	237.35	1201019	839972
61803894301	Other secondary	9.92	240.90	1200224	852309
61803895001	Diversion point	784.15	216.42	1219753	837734
61803896001	Diversion point	838.35	208.28	1226719	835849
61803896501	Return flow	8.71	205.12	1229197	837908
61803896502	Return flow	838.91	207.81	1227176	835325
61803897301	Other secondary	838.81	208.07	1227016	835698
61803898001	Diversion point	838.91	207.81	1227195	835320
61803899001	Diversion point	841.20	206.40	1227798	834467
61803899002	Diversion point	843.17	206.03	1228133	834267

61803899003	Diversion point	844.25	205.76	1228495	834518
61803900001	Diversion point	861.63	201.19	1231303	832383
61803900002	Diversion point	861.76	200.81	1231370	832853
61803900003	Diversion point	861.86	200.49	1231636	833086
61803900004	Diversion point	861.96	199.92	1231983	832516
61803900005	Diversion point	862.01	199.76	1232135	832261
61803900006	Diversion point	388.00	200.46	1232402	833380
61803900007	Diversion point	388.00	200.46	1232401	833374
61803900008	Diversion point	388.17	200.14	1232238	832912
61803900301	Other secondary	1.50	207.11	1227330	833492
61803901001	Diversion point	0.34	242.54	1209700	867194
61803901301	Other secondary	0.34	242.54	1209698	867191
61803902001	Diversion point	6.47	244.98	1208048	872706
61803902301	Other secondary	6.47	244.98	1208049	872705
61803903301	Other secondary	3.88	243.96	1214194	877734
61803904001	Diversion point	26.99	232.52	1219613	867646
61803904401	Other secondary	0.01	232.76	1219359	867623
61803904402	Other secondary	0.04	233.33	1219135	868102
61803905301	Other secondary	7.14	227.43	1216317	857669
61803906001	Diversion point	32.72	222.51	1222099	856416
61803906301	Other secondary	32.72	222.51	1222099	856416
61803906302	Other secondary	32.76	222.40	1222149	856274
61803906303	Other secondary	33.18	221.94	1222565	855828
61803907301	Other secondary	1257.85	196.26	1233303	828521
61803908001	Diversion point	1271.38	193.21	1234785	827068
61803908002	Diversion point	1270.55	194.40	1234450	827443
61803908003	Diversion point	1270.40	194.48	1234089	827581
61805172001	Diversion point	2047.64	203.25	1229944	816882
61805172002	Diversion point	2098.86	183.32	1242859	814086
61805172301	Other secondary	2047.64	203.25	1229945	816881
61805172302	Other secondary	2098.86	183.32	1242860	814087
61805173001	Diversion point	10122.36	15.74	1304818	708758
61805173002	Diversion point	64.04	9.69	1315130	707640
61805173003	Diversion point	5.04	9.86	1313093	708260
61805173501	Return flow	0.54	15.66	1305262	710000
61805173502	Return flow	3.64	11.58	1311042	709623
61805174001	Diversion point	10122.36	15.74	1304814	708759
61805174002	Diversion point	64.04	9.69	1315129	707639
61805174003	Diversion point	5.04	9.86	1313093	708260
61805174501	Return flow	0.54	15.66	1305261	710000

61805174502	Return flow	3.64	11.58	1311040	709621
61805175001	Diversion point	10122.36	15.74	1304822	708756
61805175002	Diversion point	64.04	9.69	1315129	707638
61805175003	Diversion point	5.04	9.86	1313092	708260
61805175501	Return flow	0.54	15.66	1305261	710001
61805175502	Return flow	3.64	11.58	1311040	709621
61805176001	Diversion point	10122.36	15.74	1304823	708756
61805176002	Diversion point	64.04	9.69	1315127	707637
61805176003	Diversion point	5.04	9.86	1313092	708260
61805176501	Return flow	0.54	15.66	1305261	710002
61805176502	Return flow	3.64	11.58	1311040	709621
61805177001	Diversion point	10122.36	15.74	1304814	708759
61805177002	Diversion point	64.04	9.69	1315127	707636
61805177003	Diversion point	5.04	9.86	1313092	708260
61805177501	Return flow	0.54	15.66	1305262	709999
61805177502	Return flow	3.64	11.58	1311039	709620
61805178001	Diversion point	10122.36	15.74	1304822	708756
61805178002	Diversion point	64.04	9.69	1315128	707638
61805178003	Diversion point	5.04	9.86	1313091	708261
61805178501	Return flow	0.54	15.66	1305261	710002
61805178502	Return flow	3.64	11.58	1311039	709621
61805484301	Other secondary	6189.11	15.74	1304803	708764
61805485001	Diversion point	5197.50	49.69	1291430	739741
61805486001	Diversion point	5093.70	68.16	1278891	751096
61805486002	Diversion point	493.42	51.11	1276510	732315
61805486301	Other secondary	493.42	51.11	1276510	732315
61805488001	Diversion point	1665.28	268.21	1186894	833583
61805488002	Diversion point	1695.67	260.10	1189474	826999
61805488003	Diversion point	1737.23	254.46	1193564	821994
61805488004	Diversion point	1759.10	246.30	1199350	820056
61805488301	Other secondary	1665.28	268.21	1186895	833583
61805488302	Other secondary	1695.67	260.10	1189474	826999
61805488303	Other secondary	1737.23	254.46	1193564	821994
61805488304	Other secondary	1759.10	246.30	1199351	820056
61805488501	Return flow	1737.23	254.46	1193569	821992
61805488502	Return flow	1695.67	260.10	1189474	826999
61805488503	Return flow	1737.23	254.46	1193565	821992
61805488504	Return flow	1759.47	245.22	1200122	820920
61805488505	Return flow	1670.74	266.14	1188873	832031

APPENDIX C: SAN ANTONIO BASIN RESULTS

C.1 INTRODUCTION

The following appendix contains a table of watershed parameters for all of the control points in the San Antonio River basin. The table includes the control point identification number, type of control point, drainage area in square miles, flowlength to outlet in miles, and the x and y coordinates of the control point location based on the TSMS Albers projection described in Chapter 3.

ID	Type	Area (mi^2)	Flowlength (mi)	X-coord.	Y-coord.
17	Other primary	8.19	239.88	1141205	820193
18	Stream gage	44.11	225.83	1145844	805859
19	Stream gage	136.04	240.27	1151867	817732
20	Stream gage	187.04	220.40	1153861	800111
21	Stream gage	633.63	291.08	1103175	819853
22	Other primary	15.60	286.46	1106384	816556
23	Stream gage	648.84	286.46	1106384	816556
25	Other primary	58.27	287.55	1114293	816171
27	Stream gage	961.51	226.85	1137676	789273
28	Stream gage	1310.35	215.59	1148255	788584
29	Stream gage	1737.49	202.78	1159610	786703
30	Other primary	9.41	203.90	1159010	787572
31	Stream gage	64.55	200.06	1165646	789759
32	Stream gage	2107.81	151.70	1188440	755639
33	Stream gage	68.32	275.27	1125713	845983
34	Stream gage	273.97	219.28	1163329	826565
35	Stream gage	825.42	139.12	1201350	762803
36	Stream gage	239.26	118.14	1216886	752675
37	Stream gage	3906.02	63.15	1255367	723509
38	Stream gage	10122.30	6.97	1304639	708808
241	Other primary	4.45	284.36	1105203	813821
242	Other primary	7.20	282.34	1107363	813859
261	Other primary	59.76	252.11	1132584	818585
262	Other primary	28.06	256.28	1126769	819655
263	Other primary	11.78	259.24	1119812	820932
901	Confluence	107.65	354.96	1065586	855027
902	Confluence	50.53	278.56	1122389	847713
903	Confluence	24.11	260.03	1126488	824108
904	Confluence	56.08	255.02	1132761	822256
905	Confluence	475.40	186.56	1180626	809544
906	Confluence	755.52	149.25	1196262	773121
907	Confluence	3143.40	128.97	1207018	756104
908	Confluence	3570.33	110.25	1219272	744714
909	Confluence	831.92	249.02	1121266	797350
910	Confluence	1045.68	224.89	1139667	788060
911	Confluence	1298.66	218.04	1146116	789699
912	Confluence	1310.03	216.14	1147923	788956
913	Confluence	357.45	213.49	1151844	791754

914	Confluence	1719.80	208.93	1154518	786466
915	Confluence	128.13	216.13	1151052	794740
916	Confluence	1846.69	193.52	1168399	785071
917	Confluence	1939.38	182.73	1175172	778027
918	Confluence	1954.60	179.92	1176827	775819
11903220001	Diversion point	55.01	290.40	1115350	819278
11903220301	Other secondary	55.01	290.40	1115348	819277
11903431001	Diversion point	833.44	134.55	1203121	760734
11903476001	Diversion point	1.54	262.79	1124119	826044
11903476002	Diversion point	1.54	262.79	1124120	826044
11903476301	Other secondary	1.55	262.79	1124121	826044
11903693301	Other secondary	0.83	330.13	1088056	849803
11903752001	Diversion point	12.74	286.59	1114485	852321
11903767001	Diversion point	2238.79	140.91	1196495	757016
11903803001	Diversion point	3182.58	116.05	1216894	748587
11903808001	Diversion point	2107.17	152.63	1187287	755826
11903808002	Diversion point	2107.26	152.46	1187503	755909
11903824301	Other secondary	328.17	323.15	1089888	839945
11903837001	Diversion point	1904.07	185.28	1174178	780771
11903851001	Diversion point	2156.99	143.36	1193928	758738
11903852001	Diversion point	2156.20	143.90	1193198	758537
11903853301	Other secondary	3.79	332.99	1082582	844003
11903861001	Diversion point	2067.48	160.53	1183883	763155
11903887001	Diversion point	1740.43	199.79	1162989	784114
11903888001	Diversion point	1333.46	211.65	1151773	785808
11903897001	Diversion point	3.33	182.86	1175092	778133
11903897101	Other secondary	1936.02	182.81	1175292	778099
11903897201	Other secondary	1904.79	183.34	1175132	778664
11903897401	Other secondary	0.00	183.29	1174675	778212
11903898001	Diversion point	32.45	231.69	1147737	812984
11903909301	Other secondary	2.06	331.72	1084438	844155
11903944301	Other secondary	0.69	320.95	1093521	842461
11903944302	Other secondary	0.81	320.87	1093383	842315
11903949301	Other secondary	12.27	322.66	1101633	846405
11903994101	Other secondary	2051.40	161.50	1183360	763596
11903994201	Other secondary	2047.43	163.58	1182351	765289
11904001301	Other secondary	8.44	284.06	1117403	846519
11904002101	Other secondary	807.32	144.00	1199865	767465
11904002201	Other secondary	773.51	144.15	1199772	767780
11904025301	Other secondary	860.69	243.94	1125467	798903

11904025302	Other secondary	831.92	249.02	1121276	797366
11904025501	Return flow	860.67	244.07	1125306	798961
11904025502	Return flow	831.92	249.02	1121274	797363
11904026301	Other secondary	12.26	320.62	1092562	837497
11904051301	Other secondary	0.65	243.69	1155757	821445
11904105001	Diversion point	2.79	206.73	1161571	820557
11904105002	Diversion point	2.79	206.73	1161572	820552
11904105301	Other secondary	2.79	206.73	1161571	820546
11904117001	Diversion point	3782.70	79.07	1241435	723581
11904121001	Diversion point	1886.36	188.93	1171428	783010
11904134101	Other secondary	964.72	225.10	1139392	788264
11904134201	Other secondary	963.94	225.62	1138977	788715
11904135101	Other secondary	1050.29	224.26	1140504	787692
11904135201	Other secondary	963.94	225.67	1138970	788715
11904136101	Other secondary	1051.89	221.76	1142912	788401
11904136201	Other secondary	1050.30	224.21	1140547	787689
11904137101	Other secondary	237.36	217.99	1146087	789746
11904137201	Other secondary	1051.89	221.76	1142911	788401
11904138101	Other secondary	1059.36	220.85	1143588	788924
11904138201	Other secondary	1051.40	222.76	1141967	788224
11904139101	Other secondary	227.87	222.59	1140694	791513
11904139201	Other secondary	226.75	224.24	1139180	791567
11904140101	Other secondary	680.95	279.20	1107957	810817
11904140102	Other secondary	664.42	280.27	1106894	811723
11904140201	Other secondary	680.89	279.44	1107842	811158
11904140202	Other secondary	663.93	281.24	1107971	812578
11904141001	Diversion point	214.83	225.41	1139220	792928
11904149001	Diversion point	762.79	271.51	1105756	805189
11904151001	Diversion point	790.06	258.37	1111572	796540
11904159001	Diversion point	753.09	273.45	1105763	806483
11904170101	Other secondary	682.11	277.65	1107602	809487
11904170201	Other secondary	682.12	277.54	1107550	809529
11904181001	Diversion point	1737.01	203.28	1159002	786846
11904181002	Diversion point	1737.49	202.78	1159615	786703
11904181101	Other secondary	1746.16	199.57	1163125	784291
11904181201	Other secondary	1740.43	199.73	1162997	784135
11904187001	Diversion point	227.76	222.86	1140268	791479
11904202301	Other secondary	17.86	228.45	1141757	807437
11904211301	Other secondary	5.51	286.50	1114689	846549
11904211302	Other secondary	5.53	286.39	1114800	846590

11904211303	Other secondary	5.62	286.05	1115203	846434
11904211304	Other secondary	0.68	286.08	1115288	846109
11904211305	Other secondary	0.60	286.30	1115053	845945
11904211306	Other secondary	0.57	286.59	1114999	845751
11904211307	Other secondary	0.37	286.95	1114431	846235
11904294001	Diversion point	7.20	203.69	1166457	794423
11904294301	Other secondary	7.19	203.74	1166458	794427
11904350301	Other secondary	0.36	223.19	1163292	831390
11904350302	Other secondary	0.52	223.01	1163405	831104
11904361101	Other secondary	17.20	199.05	1166855	808414
11904361201	Other secondary	16.56	199.68	1166052	808662
11904362001	Diversion point	16.20	199.99	1165663	808833
11904362002	Diversion point	16.22	199.79	1165859	808695
11904367001	Diversion point	753.56	272.24	1106166	805791
11904407001	Diversion point	2232.39	142.88	1194450	758740
11904434001	Diversion point	800.70	254.93	1115447	796002
11904440301	Other secondary	7.79	229.50	1142281	810230
11904484001	Diversion point	2083.98	156.01	1186467	759090
11904490001	Diversion point	2094.01	153.33	1186649	756476
11904495101	Other secondary	1903.77	185.65	1174422	781282
11904495201	Other secondary	1902.30	186.46	1173701	781638
11904496001	Diversion point	14.01	201.20	1164274	808422
11904496301	Other secondary	14.01	201.20	1164270	808421
11904497101	Other secondary	16.56	199.68	1166054	808662
11904497201	Other secondary	15.52	200.21	1165396	808787
11904497401	Other secondary	0.04	199.92	1165798	808668
11904498001	Diversion point	13.20	202.07	1162996	808563
11904498002	Diversion point	13.51	201.82	1163413	808395
11904499001	Diversion point	13.65	201.58	1163758	808329
11904503101	Other secondary	2094.12	153.18	1186760	756352
11904503201	Other secondary	2093.22	153.71	1186194	756346
11904510301	Other secondary	0.25	250.26	1146855	828366
11904510302	Other secondary	0.43	250.13	1146948	828187
11904510303	Other secondary	0.09	250.23	1146950	828374
11904512001	Diversion point	3452.55	112.47	1218649	747134
11904536101	Other secondary	2146.92	148.95	1189994	755265
11904536102	Other secondary	2147.35	148.49	1190392	755630
11904536201	Other secondary	2146.89	149.22	1189770	755123
11904536202	Other secondary	2147.29	148.73	1190211	755425
11904538001	Diversion point	2152.60	146.24	1191691	757476

11904538002	Diversion point	2152.31	146.75	1191034	757338
11904561001	Diversion point	833.87	134.00	1203831	760452
11905002001	Diversion point	2275.38	132.42	1203408	754443
11905043001	Diversion point	3572.32	107.80	1221272	744264
11905044001	Diversion point	3181.84	117.47	1215573	748904
11905062001	Diversion point	2146.92	148.95	1190005	755273
11905079001	Diversion point	3875.00	72.57	1248167	723225
11905097001	Diversion point	55.87	348.06	1068536	847901
11905126001	Diversion point	1902.42	186.25	1173952	781743
11905126002	Diversion point	1903.29	186.01	1174242	781734
11905171101	Other secondary	2027.34	170.39	1179110	770054
11905171201	Other secondary	2026.15	172.23	1178409	771390
11905182001	Diversion point	633.63	170.62	1187349	794308
11905194101	Other secondary	1941.06	180.07	1176627	776007
11905194201	Other secondary	1941.00	180.37	1176449	776364
11905202101	Other secondary	2083.95	156.06	1186460	759181
11905202201	Other secondary	2083.94	156.14	1186496	759281
11905211001	Diversion point	860.73	243.73	1125484	798592
11905211401	Other secondary	0.00	243.66	1125710	798506
11905211402	Other secondary	0.07	243.34	1125822	798221
11905214001	Diversion point	773.15	144.52	1199822	768317
11905218001	Diversion point	721.82	158.02	1194115	783360
11905218002	Diversion point	721.84	157.89	1194129	783238
11905220001	Diversion point	3875.01	72.52	1248273	723224
11905224101	Other secondary	480.14	182.52	1181169	805054
11905224201	Other secondary	478.54	183.25	1181319	805847
11905239001	Diversion point	2156.11	144.08	1192981	758617
11905243001	Diversion point	13.52	179.92	1176820	775865
11905262001	Diversion point	180.55	226.16	1153055	804681
11905264001	Diversion point	1940.71	181.29	1176027	776810
11905265101	Other secondary	13.38	201.87	1163321	808433
11905265201	Other secondary	13.20	202.07	1162993	808565
11905266001	Diversion point	1737.48	202.83	1159665	786762
11905289001	Diversion point	26.38	219.91	1155791	799272
11905296001	Diversion point	2151.85	147.23	1190605	757053
11905298301	Other secondary	0.94	195.43	1170059	787082
11905298302	Other secondary	0.93	198.65	1169369	788162
11905298303	Other secondary	0.71	195.86	1170465	787613
11905306001	Diversion point	2242.05	136.81	1199665	754140
11905307001	Diversion point	1957.12	177.58	1176859	773362

11905308001	Diversion point	773.04	145.07	1200045	769088
11905313001	Diversion point	3705.51	90.27	1233170	729574
11905320001	Diversion point	2027.42	170.06	1178790	770120
11905323001	Diversion point	2152.35	146.58	1191207	757477
11905333001	Diversion point	2154.84	145.54	1192309	757089
11905333002	Diversion point	2154.88	145.37	1192406	757252
11905337001	Diversion point	3.50	223.57	1142671	799056
11905339001	Diversion point	1.31	336.83	1079179	835439
11905342301	Other secondary	61.56	346.93	1069981	847765
11905367101	Other secondary	3143.52	128.44	1207682	756027
11905367201	Other secondary	2286.53	129.75	1206346	755474
11905368101	Other secondary	3146.77	126.57	1208893	755341
11905368201	Other secondary	3143.40	128.90	1207047	756096
11905391001	Diversion point	104.02	220.75	1148415	800411
11905391002	Diversion point	104.06	220.65	1148417	800287
11905391003	Diversion point	108.39	219.88	1148609	799128
11905391004	Diversion point	110.83	218.69	1149548	797793
11905391005	Diversion point	112.58	217.16	1150355	796009
11905391301	Other secondary	104.02	220.70	1148415	800403
11905391302	Other secondary	108.58	219.65	1148861	798913
11905391501	Return flow	113.08	216.30	1151074	795017
11905391502	Return flow	106.08	220.25	1148494	799638
11905391503	Return flow	108.66	219.52	1149033	798800
11905391504	Return flow	111.17	217.99	1149608	796928
11905391505	Return flow	112.63	217.03	1150473	795850
11905395001	Diversion point	2033.19	167.61	1178612	767357
11905399001	Diversion point	4.52	130.18	1202050	735969
11905399301	Other secondary	4.52	130.12	1202066	735987
11905423001	Diversion point	0.10	260.33	1130092	827922
11905423301	Other secondary	0.06	260.70	1130274	828500
11905423302	Other secondary	0.18	259.57	1131044	828065
11905423303	Other secondary	0.06	260.09	1130225	827488
11905423304	Other secondary	0.10	260.33	1130091	827923
11905423401	Other secondary	0.00	259.74	1129784	827169
11905455001	Diversion point	2156.16	143.95	1193088	758581
11905469001	Diversion point	41.99	257.08	1133850	824171
11905469002	Diversion point	41.99	257.08	1133850	824171
11905469301	Other secondary	41.99	257.08	1133850	824171
11905478001	Diversion point	3873.42	74.52	1245536	722560
11905478401	Other secondary	0.00	75.16	1245398	722868

11905489004	Diversion point	4164.34	13.48	1297679	708456
11905499001	Diversion point	2031.18	169.05	1178765	768781
11905503001	Diversion point	24.89	248.68	1144933	822220
11905503301	Other secondary	24.89	248.68	1144932	822221
11905517001	Diversion point	176.57	242.25	1134388	806721
11905517401	Other secondary	0.00	242.41	1134378	806306
11905532001	Diversion point	2152.42	146.32	1191433	757606
11905549001	Diversion point	13.33	246.80	1124055	801492
11905549002	Diversion point	13.73	246.15	1123969	800819
11905549003	Diversion point	17.31	242.28	1126849	797207
11905549301	Other secondary	13.34	246.74	1124105	801471
11905549302	Other secondary	13.73	246.15	1123971	800819
11905559001	Diversion point	684.03	161.18	1192555	787121
11905577001	Diversion point	1727.09	204.05	1157963	786756
11905577401	Other secondary	0.00	204.11	1158105	786559
11905587001	Diversion point	2068.16	159.04	1184282	761639
11905596001	Diversion point	960.21	228.36	1136359	789386
11905598001	Diversion point	1.54	238.88	1129432	795549
11905598301	Other secondary	1.23	238.94	1129430	795556
61901142001	Diversion point	8.05	289.39	1111618	852642
61901143001	Diversion point	19.50	282.52	1118865	851254
61901143002	Diversion point	19.50	282.52	1118867	851254
61901143301	Other secondary	19.50	282.52	1118858	851254
61901144001	Diversion point	8.20	284.43	1116988	846388
61901144301	Other secondary	8.20	284.43	1116988	846388
61901144302	Other secondary	8.60	283.83	1117759	846412
61901144303	Other secondary	4.32	283.92	1117866	845827
61901145301	Other secondary	15.06	276.87	1124928	841457
61901146001	Diversion point	285.44	210.91	1168837	821918
61901146002	Diversion point	285.58	210.70	1169021	821710
61901146003	Diversion point	285.64	210.48	1169280	821758
61901148001	Diversion point	617.82	173.01	1186846	796251
61901149001	Diversion point	618.02	172.49	1187210	795743
61901150001	Diversion point	633.92	169.65	1188314	793754
61901151001	Diversion point	635.26	169.10	1188187	793095
61901152001	Diversion point	646.76	167.82	1188574	792033
61901153001	Diversion point	647.35	166.49	1190110	791647
61901154001	Diversion point	652.39	165.36	1190274	790651
61901155001	Diversion point	654.15	164.68	1190837	789921
61901156001	Diversion point	655.42	163.50	1191464	788997

61901157001	Diversion point	683.24	162.21	1192043	788250
61901157002	Diversion point	683.27	162.10	1192034	788155
61901158001	Diversion point	684.06	160.98	1192651	786870
61901159001	Diversion point	684.67	160.76	1192729	786464
61901160001	Diversion point	727.68	156.51	1194780	781500
61901161001	Diversion point	747.97	151.64	1197466	776288
61901162001	Diversion point	749.42	150.02	1196952	774116
61901163001	Diversion point	5.59	149.41	1195993	773267
61901163002	Diversion point	755.53	149.05	1196328	772981
61901163301	Other secondary	5.12	149.35	1195965	773296
61901164001	Diversion point	759.10	147.68	1197569	771310
61901165001	Diversion point	762.41	147.42	1197577	771010
61901166001	Diversion point	762.46	147.29	1197670	770842
61901167001	Diversion point	807.79	143.32	1199561	766768
61901168001	Diversion point	833.00	134.71	1202860	760770
61901168002	Diversion point	829.22	135.42	1202111	760630
61901168003	Diversion point	827.84	136.00	1202542	761154
61901169301	Other secondary	50.75	278.05	1123100	847674
61901170001	Diversion point	6.38	205.74	1161904	812289
61901170301	Other secondary	6.37	205.74	1161914	812305
61901171001	Diversion point	481.77	180.35	1182569	802231
61901171002	Diversion point	481.75	180.30	1182499	802300
61901931001	Diversion point	104.09	220.57	1148433	800230
61901931301	Other secondary	104.09	220.57	1148432	800234
61901933001	Diversion point	108.39	219.88	1148608	799128
61901933002	Diversion point	108.39	219.88	1148608	799128
61901942001	Diversion point	108.39	219.88	1148609	799128
61901942301	Other secondary	108.58	219.65	1148864	798911
61901944001	Diversion point	110.88	218.61	1149627	797714
61901951301	Other secondary	1.64	215.69	1149977	794012
61901959001	Diversion point	358.25	212.48	1152398	790996
61901960001	Diversion point	135.98	240.50	1151814	817946
61901962001	Diversion point	166.35	232.08	1152920	809670
61901965001	Diversion point	184.56	222.24	1152655	801933
61901966001	Diversion point	358.25	212.48	1152393	790997
61901966301	Other secondary	358.25	212.48	1152395	790997
61902019001	Diversion point	358.25	212.48	1152388	790998
61902019301	Other secondary	358.25	212.48	1152391	790997
61902103001	Diversion point	48.22	367.52	1055445	855295
61902103002	Diversion point	50.91	367.36	1055665	855323

61902103003	Diversion point	10.18	367.59	1055462	856436
61902103004	Diversion point	10.31	367.44	1055642	856318
61902103005	Diversion point	10.36	367.31	1055683	856147
61902103006	Diversion point	10.40	367.20	1055710	855973
61902103007	Diversion point	10.43	367.07	1055759	855774
61902104101	Other secondary	92.07	356.67	1063488	855944
61902104201	Other secondary	67.29	361.53	1060406	855674
61902105001	Diversion point	78.15	360.23	1061582	854808
61902105002	Diversion point	4.66	360.36	1061581	854691
61902105003	Diversion point	93.73	356.23	1063867	855397
61902105301	Other secondary	4.40	360.79	1061434	854176
61902105302	Other secondary	0.16	360.82	1061724	854116
61902105303	Other secondary	4.66	360.42	1061581	854684
61902106301	Other secondary	9.81	360.15	1060863	857830
61902107001	Diversion point	95.12	355.15	1065312	855072
61902108001	Diversion point	5.37	360.01	1062450	860138
61902108002	Diversion point	5.50	359.88	1062515	859966
61902108003	Diversion point	5.61	359.62	1062808	859822
61902108004	Diversion point	5.80	359.41	1063006	859614
61902109001	Diversion point	158.56	346.00	1071773	848957
61902110001	Diversion point	158.82	345.62	1071693	848335
61902111001	Diversion point	1.54	362.66	1053860	844216
61902111301	Other secondary	1.57	362.45	1054123	844092
61902112001	Diversion point	5.60	356.96	1059800	846282
61902113001	Diversion point	29.63	355.98	1061173	846138
61902114001	Diversion point	1.49	357.95	1060383	848317
61902114002	Diversion point	1.60	357.61	1060734	847957
61902114003	Diversion point	1.16	357.27	1061557	848223
61902115001	Diversion point	4.03	356.36	1061868	847394
61902116001	Diversion point	42.22	353.48	1063896	846370
61902116002	Diversion point	41.99	354.07	1063374	846005
61902116301	Other secondary	42.31	353.41	1063977	846333
61902117001	Diversion point	234.39	341.77	1074945	847022
61902117002	Diversion point	234.32	341.93	1074779	846948
61902118001	Diversion point	1.10	340.92	1077959	849091
61902119001	Diversion point	304.04	329.93	1084576	841766
61902120001	Diversion point	316.43	329.12	1085471	841110
61902120002	Diversion point	319.06	328.81	1085867	840951
61902121001	Diversion point	4.94	333.47	1082165	838007
61902121002	Diversion point	4.94	333.42	1082174	838053

61902121003	Diversion point	4.41	333.74	1082124	837586
61902121004	Diversion point	5.09	333.18	1082291	838320
61902122001	Diversion point	323.93	326.95	1087990	839827
61902123001	Diversion point	395.25	319.75	1092914	839267
61902123002	Diversion point	395.36	319.49	1093035	838983
61902123003	Diversion point	395.47	319.04	1093645	838783
61902124001	Diversion point	6.91	323.62	1090352	836377
61902125001	Diversion point	6.94	323.57	1090427	836391
61902126001	Diversion point	415.05	317.07	1095445	839428
61902126002	Diversion point	413.16	317.29	1095284	839219
61902127001	Diversion point	415.10	316.84	1095595	839701
61902128001	Diversion point	1.72	322.39	1099362	848270
61902128301	Other secondary	1.72	322.44	1099362	848275
61902129001	Diversion point	9.99	321.54	1098693	847266
61902129301	Other secondary	9.99	321.54	1098692	847265
61902130001	Diversion point	648.84	286.46	1106384	816556
61902130002	Diversion point	633.63	291.06	1103163	819839
61902130301	Other secondary	633.63	291.06	1103163	819839
61902130302	Other secondary	648.84	286.46	1106384	816556
61902131002	Diversion point	648.84	286.46	1106384	816556
61902132901	Other secondary	648.84	286.46	1106384	816556
61902133001	Diversion point	683.42	275.93	1107069	808060
61902134001	Diversion point	762.58	271.98	1106178	805496
61902135001	Diversion point	4.11	307.85	1115051	835917
61902135301	Other secondary	4.11	307.85	1115046	835915
61902136001	Diversion point	4.95	306.79	1114905	834321
61902136301	Other secondary	4.95	306.74	1114905	834299
61902137301	Other secondary	784.87	263.09	1109243	799357
61902138001	Diversion point	789.15	259.36	1110513	795959
61902139001	Diversion point	789.21	259.15	1110864	795981
61902140001	Diversion point	805.97	251.88	1118753	796075
61902140002	Diversion point	806.71	250.77	1119572	796901
61902140003	Diversion point	806.93	250.14	1120445	796579
61902140004	Diversion point	807.15	249.83	1120872	796361
61902140005	Diversion point	807.27	249.56	1120993	796743
61902140006	Diversion point	11.23	251.44	1118809	797866
61902140007	Diversion point	12.01	249.93	1120224	797772
61902140008	Diversion point	24.32	249.07	1121082	797380
61902141001	Diversion point	2.82	251.31	1119704	800318
61902141002	Diversion point	2.89	251.24	1119771	800228

61902141301	Other secondary	2.85	251.31	1119719	800304
61902142001	Diversion point	24.33	249.02	1121152	797380
61902144001	Diversion point	833.05	247.05	1122723	797757
61902145001	Diversion point	956.84	230.61	1134794	790947
61902145002	Diversion point	956.87	230.56	1134736	790805
61902146001	Diversion point	957.92	229.96	1134657	790029
61902147001	Diversion point	14.96	236.90	1125491	789654
61902148001	Diversion point	30.78	234.80	1127746	788757
61902149001	Diversion point	207.84	228.89	1138192	796460
61902150001	Diversion point	226.26	224.24	1139138	791676
61902151001	Diversion point	235.99	219.29	1144410	790693
61902151002	Diversion point	3.44	219.96	1144865	793234
61902151301	Other secondary	3.44	219.89	1144905	793209
61902151501	Return flow	3.41	220.09	1144772	793296
61902152001	Diversion point	9.69	217.51	1146689	790513
61902152002	Diversion point	9.69	217.51	1146689	790512
61902153001	Diversion point	9.69	217.51	1146689	790515
61902153002	Diversion point	9.69	217.51	1146689	790514
61902153003	Diversion point	9.69	217.51	1146689	790514
61902153301	Other secondary	9.69	217.51	1146689	790513
61902153302	Other secondary	37.72	229.00	1147103	809856
61902153303	Other secondary	43.94	226.37	1145912	806491
61902153304	Other secondary	44.11	225.83	1145846	805856
61902153305	Other secondary	45.21	225.10	1146592	805078
61902153501	Return flow	34.94	230.91	1148333	812109
61902153502	Return flow	45.23	225.10	1146595	805054
61902153503	Return flow	160.33	236.59	1153877	813608
61902154001	Diversion point	9.69	217.51	1146689	790516
61902155001	Diversion point	1310.69	215.54	1148758	788152
61902156001	Diversion point	1345.46	210.31	1153210	786269
61902156002	Diversion point	1347.24	209.09	1154380	786417
61902156101	Other secondary	1347.24	209.09	1154375	786416
61902156201	Other secondary	1345.46	210.37	1153191	786268
61902157001	Diversion point	363.74	210.34	1153358	788301
61902158001	Diversion point	367.61	209.62	1154312	787807
61902158002	Diversion point	371.72	209.28	1154628	787480
61902159001	Diversion point	371.83	209.13	1154589	787256
61902160001	Diversion point	1722.00	206.91	1156160	785426
61902161001	Diversion point	1727.23	203.76	1158423	786869
61902161002	Diversion point	1727.24	203.76	1158470	786872

61902161003	Diversion point	62.24	201.51	1164417	791527
61902161301	Other secondary	9.19	204.21	1158729	787850
61902161302	Other secondary	62.24	201.51	1164417	791527
61902161501	Return flow	0.40	203.16	1162956	791127
61902162002	Diversion point	62.24	201.51	1164417	791527
61902162301	Other secondary	62.24	201.51	1164417	791527
61902162302	Other secondary	1727.24	203.76	1158480	786870
61902162401	Other secondary	0.00	206.08	1165452	796961
61902163001	Diversion point	1749.79	197.17	1165204	783859
61902164001	Diversion point	94.21	193.73	1168694	785416
61902164002	Diversion point	1846.69	193.52	1168399	785067
61902165001	Diversion point	1846.79	193.05	1168658	784571
61902166001	Diversion point	1904.69	183.82	1174708	778923
61902167001	Diversion point	1904.75	183.60	1175029	779044
61902168001	Diversion point	0.28	185.52	1179506	781816
61902168301	Other secondary	0.31	185.47	1179538	781762
61902169001	Diversion point	1955.00	179.09	1177403	774843
61902169002	Diversion point	1955.13	178.65	1176795	774624
61902169003	Diversion point	1956.72	178.26	1176587	774131
61902170301	Other secondary	2.41	177.62	1172628	774962
61902171001	Diversion point	2033.69	166.32	1180185	767457
61902172001	Diversion point	2040.50	164.78	1181216	766300
61902173001	Diversion point	2046.99	164.37	1181703	765868
61902174001	Diversion point	2047.02	164.24	1181763	765680
61902175001	Diversion point	2047.42	163.65	1182322	765376
61902176101	Other secondary	2067.58	160.12	1184154	762607
61902176201	Other secondary	2067.49	160.46	1183971	763094
61902177001	Diversion point	2067.59	160.07	1184261	762608
61902178001	Diversion point	2067.65	159.78	1184639	762487
61902178002	Diversion point	2067.69	159.59	1184720	762184
61902179001	Diversion point	2068.17	158.96	1184343	761538
61902179002	Diversion point	2068.29	158.65	1184206	761052
61902180001	Diversion point	2068.17	158.96	1184352	761524
61902180002	Diversion point	2068.29	158.60	1184214	761040
61902181001	Diversion point	2077.55	157.46	1184791	760002
61902182001	Diversion point	2084.15	155.69	1186168	758768
61902183001	Diversion point	2093.19	153.86	1185976	756486
61902184001	Diversion point	2107.69	152.09	1187964	755979
61902184002	Diversion point	2107.39	152.30	1187624	755933
61902184003	Diversion point	2107.71	151.98	1188159	755933

61902185001	Diversion point	2108.05	151.16	1188362	754831
61902185002	Diversion point	2107.83	151.59	1188479	755493
61902186001	Diversion point	2239.06	140.56	1196581	756452
61902188001	Diversion point	2275.62	132.10	1203807	754576
61902189001	Diversion point	2285.31	131.01	1204877	755047
61902190001	Diversion point	3454.60	111.47	1219255	745963
61902191301	Other secondary	6.84	133.03	1195050	746268
61902192001	Diversion point	3670.47	96.21	1228693	735083
61902193001	Diversion point	3706.81	88.64	1234034	727757
61902194001	Diversion point	3706.92	88.33	1234459	727634
61902194002	Diversion point	3708.50	86.95	1236131	727188
61902195001	Diversion point	3708.63	86.39	1237031	727112
61902196001	Diversion point	3723.19	85.76	1236978	726229
61902196002	Diversion point	3723.20	85.63	1237148	726168
61902196003	Diversion point	3723.37	85.20	1237654	726599
61902196004	Diversion point	3723.67	84.19	1237673	725722
61902197001	Diversion point	3781.27	79.59	1240771	724050
61902198001	Diversion point	3792.29	76.19	1243287	723076
61902199001	Diversion point	3792.25	76.32	1243190	723159
61902199002	Diversion point	3792.40	75.89	1243646	722721
61902199003	Diversion point	3795.30	75.44	1244243	722652
61902199004	Diversion point	3795.40	74.97	1244990	722473
61904768002	Diversion point	891.52	235.69	1131395	794358
61904768301	Other secondary	50.83	233.99	1132547	794162

APPENDIX D: SAN JACINTO BASIN RESULTS

D.1 INTRODUCTION

The following appendix contains a table of watershed parameters for all of the control points in the San Jacinto River basin. The table includes the control point identification number, type of control point, drainage area in square miles, average curve number in the drainage area, mean annual precipitation in inches across the drainage area, and the x and y coordinates of the control point location based on the TSMS Albers projection described in Chapter 3.

ID	Type	Area (mi^2)	CN	Precip	X-coord.	Y-coord.
0	Stream gage	3977.81	68	46	1485002	845337
100	Return flow	0.05	70	51	1468217	850207
101	Return flow	3.86	84	51	1471652	850497
102	Return flow	3.89	84	51	1471656	850669
103	Return flow	4.04	85	51	1471642	850942
104	Return flow	992.69	78	46	1472090	851929
105	Return flow	0.26	81	51	1471950	862287
108	Return flow	91.19	81	48	1458004	847706
109	Return flow	2.49	86	51	1471481	849730
110	Return flow	987.96	78	46	1470921	851351
111	Return flow	2.47	86	51	1471464	849638
112	Return flow	987.04	78	46	1470129	851148
114	Return flow	993.13	78	46	1472268	852008
116	Return flow	2.05	78	51	1473116	851484
117	Return flow	7.67	81	50	1466640	851984
118	Return flow	768.75	79	46	1464142	852007
119	Return flow	91.01	81	48	1457869	847552
120	Return flow	612.94	77	45	1458442	849548
121	Return flow	609.32	77	45	1456606	849555
122	Return flow	0.18	80	51	1474654	849737
123	Return flow	0.41	77	51	1474834	850159
124	Return flow	88.79	80	48	1457605	846636
125	Return flow	3973.15	68	46	1481291	848333
126	Return flow	3968.64	68	46	1480544	850669
127	Return flow	1.56	85	51	1471709	848877
128	Return flow	0.41	87	50	1466239	854382
130	Return flow	0.75	77	50	1464927	851504
132	Return flow	983.65	78	46	1467115	851986
133	Return flow	2.03	74	46	1427935	838574
134	Return flow	2.16	73	46	1418924	869483
135	Return flow	1.58	73	51	1473408	850733
136	Return flow	0.02	70	51	1474940	851579
137	Return flow	730.01	78	46	1461351	849765
138	Return flow	15.43	91	48	1454413	857689
140	Return flow	986.99	78	46	1469977	851166
141	Return flow	984.17	78	46	1467761	851393
142	Return flow	0.31	70	51	1467889	850584
143	Return flow	3958.58	68	46	1477130	851964

144	Return flow	768.66	79	46	1464013	851915
145	Return flow	1.16	67	51	1472307	860141
146	Return flow	1.16	67	51	1472306	860141
147	Return flow	488.28	65	45	1432312	909340
148	Return flow	29.24	66	50	1466984	857530
149	Return flow	6.15	81	50	1467256	848559
150	Return flow	0.01	92	51	1469024	844931
151	Return flow	8.83	87	50	1461651	848719
152	Return flow	93.95	80	46	1442313	845743
153	Return flow	1.75	75	46	1433299	836709
154	Return flow	2896.01	65	46	1475367	859408
155	Return flow	2.10	80	51	1472295	856932
156	Return flow	27.40	87	48	1460926	854358
157	Return flow	2.07	76	50	1462545	840413
158	Return flow	2.07	76	50	1462544	840413
159	Return flow	2900.61	65	46	1476569	858016
160	Return flow	0.08	92	49	1457245	850696
161	Return flow	22.52	75	46	1439294	837026
162	Return flow	1.89	82	50	1457809	840649
163	Return flow	5.92	79	47	1447225	875675
164	Return flow	34.96	72	46	1442928	873856
165	Return flow	2.26	59	49	1460066	866043
166	Return flow	8.64	71	45	1426410	841070
167	Return flow	23.24	72	46	1441061	874634
168	Return flow	17.79	73	45	1430634	842218
169	Return flow	4.05	79	47	1454751	872123
170	Return flow	1771.56	67	45	1457530	883115
171	Return flow	19.95	70	43	1417529	856766
172	Return flow	3.42	77	49	1462891	885449
173	Return flow	17.61	73	46	1439661	873353
174	Return flow	6.27	73	46	1430294	873564
176	Return flow	40.50	84	47	1455638	863018
177	Return flow	5.47	92	49	1457966	847796
178	Return flow	34.30	76	47	1443893	838221
179	Return flow	47.38	76	47	1450400	840393
180	Return flow	12.76	92	48	1453964	858464
181	Return flow	291.57	71	44	1428379	852504
182	Return flow	79.34	78	46	1439579	844599
183	Return flow	3.64	79	50	1461620	841484
184	Return flow	10.93	73	46	1437440	862242

185	Return flow	194.69	74	48	1461935	856106
186	Return flow	469.78	76	45	1453790	852682
187	Return flow	6.81	70	45	1424418	841784
188	Return flow	37.95	73	46	1434231	865498
189	Return flow	5.07	72	46	1437292	835377
190	Return flow	1.53	75	46	1428065	846490
191	Return flow	14.97	71	45	1426066	847333
192	Return flow	1.46	85	51	1471682	848506
193	Return flow	79.34	78	46	1439653	844657
194	Return flow	1.04	70	51	1471655	858591
195	Return flow	308.93	72	44	1433670	850983
196	Return flow	0.01	85	45	1422500	886031
197	Return flow	12.20	71	42	1402699	852974
198	Return flow	2.85	72	47	1454953	877218
199	Return flow	0.44	55	45	1425323	950497
200	Return flow	1.02	81	46	1421897	871806
201	Return flow	5.11	78	46	1423044	870484
202	Return flow	50.50	78	45	1431665	891909
203	Return flow	2.56	74	47	1440139	869575
204	Return flow	0.01	70	46	1430999	878593
205	Return flow	0.39	78	47	1439227	893471
206	Return flow	2.05	84	46	1433856	876013
207	Return flow	1.75	74	46	1426436	840717
208	Return flow	0.39	87	46	1436316	882168
209	Return flow	229.02	80	44	1425764	877499
210	Return flow	249.42	80	44	1433091	880370
211	Return flow	0.16	63	47	1446292	883570
212	Return flow	1.39	71	47	1443907	883998
213	Return flow	2.30	73	43	1409659	853043
214	Return flow	0.26	70	47	1433808	869733
215	Return flow	0.08	78	46	1427675	863505
216	Return flow	1.03	73	46	1427501	872884
217	Return flow	282.62	80	44	1439015	883243
218	Return flow	14.58	70	43	1414429	856420
219	Return flow	1.54	70	45	1419011	859805
220	Return flow	16.16	68	50	1473726	870076
221	Return flow	33.87	63	46	1434759	894210
222	Return flow	765.03	71	44	1452141	883628
223	Return flow	247.80	80	44	1430972	879312
224	Return flow	7.87	79	46	1415460	865261

225	Return flow	20.56	74	45	1420612	863308
226	Return flow	0.08	56	49	1462369	878885
227	Return flow	22.15	75	46	1428856	866175
228	Return flow	0.07	70	46	1434201	834759
229	Return flow	0.92	70	46	1426746	870348
230	Return flow	42.25	73	46	1446864	873283
231	Return flow	0.02	70	43	1408185	856034
232	Return flow	2.45	70	45	1419923	846167
233	Return flow	15.63	75	45	1417068	864205
234	Return flow	2.44	70	44	1415463	858707
235	Return flow	1.72	72	50	1462631	859605
236	Return flow	22.18	71	44	1411768	862711
237	Return flow	0.72	64	47	1444630	887560
238	Return flow	2.97	81	45	1434114	885851
239	Return flow	284.31	80	44	1440574	883383
240	Return flow	0.87	70	46	1436804	873773
241	Return flow	24.39	70	42	1410910	854014
242	Return flow	4.93	70	43	1412593	849717
243	Return flow	16.42	73	46	1437206	872802
244	Return flow	4.51	71	45	1413786	864326
245	Return flow	13.48	74	46	1420488	866243
246	Return flow	283.17	80	44	1439181	883262
247	Return flow	1.36	70	43	1413674	857923
248	Return flow	3.70	85	45	1429746	882418
249	Return flow	2.36	72	45	1423375	848277
250	Return flow	3.15	70	45	1421803	842869
251	Return flow	9.71	80	46	1425368	869765
252	Return flow	10.07	72	46	1433539	873375
253	Return flow	0.84	70	46	1435398	876604
254	Return flow	12.42	78	46	1426657	869070
255	Return flow	0.15	70	47	1444787	875078
256	Return flow	3.43	63	47	1437517	901468
257	Return flow	1.99	76	46	1439057	877929
258	Return flow	1.08	85	47	1442576	878513
259	Return flow	0.45	71	45	1422624	844511
260	Return flow	3.29	71	49	1461862	895505
261	Return flow	9.05	72	46	1440297	876092
262	Return flow	2.36	85	47	1443603	880395
263	Return flow	1.24	85	47	1442916	879044
264	Return flow	30.33	71	42	1414219	851264

265	Return flow	9.57	60	46	1433518	900983
266	Return flow	0.11	85	47	1442457	878265
267	Return flow	22.94	66	50	1467093	860966
268	Return flow	6.26	78	46	1418150	867835
269	Return flow	0.73	70	47	1445776	874269
270	Return flow	229.48	80	44	1426239	877245
271	Return flow	18.83	74	45	1419043	864085
272	Return flow	2.71	73	47	1440316	869485
273	Return flow	85.02	70	42	1410597	847442
274	Return flow	0.17	85	46	1411484	876733
275	Return flow	5.51	80	46	1416980	868695
276	Return flow	83.92	70	42	1409288	847813
277	Return flow	0.44	70	46	1429727	870386
278	Return flow	262.87	80	44	1434065	881260
279	Return flow	21.98	75	46	1428751	866279
280	Return flow	10.32	71	46	1422823	853395
281	Return flow	91.19	81	48	1458007	847710
1001	WQS point	2900.72	65	46	1476415	857860
1002	WQS point	2837.05	65	46	1468896	871810
1003	WQS point	393.00	61	48	1466049	889804
1004	WQS point	998.36	64	45	1455843	883767
1005	WQS point	3977.76	68	46	1484909	845584
1006	WQS point	1036.64	78	47	1474131	854551
1007	WQS point	771.83	79	46	1466349	852413
1008	WQS point	770.59	71	44	1455791	883707
1009	WQS point	328.47	79	44	1451346	883556
1010	WQS point	374.83	60	48	1465539	889624
1011	WQS point	157.08	58	49	1464182	893633
1012	WQS point	450.02	65	45	1425469	918533
1013	WQS point	461.21	75	45	1448951	853857
1014	WQS point	345.79	73	44	1442721	853142
1015	WQS point	276.38	64	44	1420497	905397
1016	WQS point	124.26	72	47	1460105	863026
1017	WQS point	110.46	81	47	1446801	855068
10061	WQS point	4.25	85	51	1471997	851754
10071	WQS point	15.97	89	50	1461168	849763
8067650	Stream gage	456.86	65	45	1427618	916968
8068000	Stream gage	828.74	64	45	1436252	906511
8068500	Stream gage	403.28	65	44	1438865	891717
8068740	Stream gage	131.09	80	43	1412481	873803

8069000	Stream gage	284.13	80	44	1439928	883427
8070000	Stream gage	324.58	61	47	1469702	918147
8070500	Stream gage	105.35	61	47	1451025	908779
8071000	Stream gage	117.42	56	49	1464036	906351
8071500	Stream gage	2813.56	65	46	1468754	880083
8073500	Stream gage	285.28	71	44	1424110	852342
8074000	Stream gage	346.06	73	44	1443140	852970
8074500	Stream gage	86.76	78	47	1444175	854631
8075000	Stream gage	94.41	80	46	1443076	845934
8075500	Stream gage	65.80	78	48	1455046	843845
8076000	Stream gage	63.94	75	47	1452208	870879
11004038001	Diversion point	1.78	63	47	1432042	914418
11004038301	Other secondary	1.78	63	47	1432042	914418
11004066001	Diversion point	27.36	71	44	1415727	860289
11004066401	Other secondary	0.00	59	45	1415879	860992
11004066402	Other secondary	0.01	65	45	1415764	860808
11004188001	Diversion point	9.55	62	45	1428909	900869
11004188301	Other secondary	9.55	62	45	1428907	900871
11004248001	Diversion point	3.20	60	47	1432753	921895
11004248301	Other secondary	3.20	60	47	1432753	921895
11004248401	Other secondary	0.01	84	47	1432356	921715
11004255301	Other secondary	0.20	74	47	1435040	930196
11004255302	Other secondary	0.16	83	47	1434530	930620
11004255303	Other secondary	0.06	56	47	1434367	929531
11004309301	Other secondary	0.13	56	47	1440797	937503
11004309302	Other secondary	0.20	55	47	1440884	936940
11004375001	Diversion point	33.42	77	46	1443428	837534
11004375501	Return flow	33.43	77	46	1443455	837567
11004523301	Other secondary	0.20	59	46	1426150	925244
11005055001	Diversion point	297.86	80	44	1443230	883601
11005055002	Diversion point	300.19	80	44	1444970	883931
11005055401	Other secondary	0.00	59	47	1443390	883521
11005055402	Other secondary	0.00	59	47	1444792	883862
11005191001	Diversion point	996.28	78	46	1473170	853020
11005191501	Return flow	996.27	78	46	1473041	852885
11005209001	Diversion point	39.64	74	46	1436077	864824
11005209401	Other secondary	0.00	92	47	1436129	865438
11005209402	Other secondary	0.01	92	47	1435948	865560
11005209403	Other secondary	0.04	88	47	1436142	865855
11005209404	Other secondary	0.00	72	47	1436395	865717

11005209405	Other secondary	0.00	72	47	1436429	865454
11005257001	Diversion point	287.38	71	44	1425810	852287
11005257401	Other secondary	0.08	90	46	1426638	852675
11005257501	Return flow	287.49	71	44	1425969	852651
11005261301	Other secondary	0.09	63	46	1431982	931263
11005299001	Diversion point	2900.72	65	46	1476357	857801
11005311001	Diversion point	53.10	74	45	1432522	842704
11005311401	Other secondary	0.00	85	46	1432386	842959
11005311402	Other secondary	0.00	92	46	1432644	842815
11005311403	Other secondary	0.00	92	46	1432709	842946
11005332001	Diversion point	28.05	71	44	1416141	859359
11005332401	Other secondary	0.00	59	45	1416973	859284
11005334001	Diversion point	2901.02	65	46	1476007	857364
11005334501	Return flow	2901.02	65	46	1476007	857364
11005336101	Other secondary	314.15	72	44	1436029	853763
11005336201	Other secondary	310.89	72	44	1434611	852732
11005336401	Other secondary	0.00	92	47	1435286	852977
11005336402	Other secondary	0.00	92	47	1435867	853656
11005340001	Diversion point	2900.34	65	46	1476475	858707
11005353001	Diversion point	711.52	78	46	1460060	849453
11005353501	Return flow	711.51	78	46	1459956	849374
11005362001	Diversion point	4.62	75	46	1429657	841228
11005362002	Diversion point	4.42	74	46	1433524	837936
11005362501	Return flow	4.44	74	46	1433561	837759
11005363001	Diversion point	289.75	71	44	1427390	852609
11005363501	Return flow	291.24	71	44	1427698	852506
11005408301	Other secondary	0.75	67	44	1415485	894869
11005408302	Other secondary	2.11	73	44	1415889	895310
11005430001	Diversion point	611.61	77	45	1458023	849835
11005430002	Diversion point	612.86	77	45	1458207	849765
11005432001	Diversion point	609.30	77	45	1456573	849569
11005432002	Diversion point	609.30	77	45	1456512	849595
11005432003	Diversion point	609.28	77	45	1456448	849624
11005436001	Diversion point	5.79	79	49	1462087	884330
11005436301	Other secondary	5.01	78	49	1461681	884719
11005436302	Other secondary	5.04	78	49	1461893	884514
11005436303	Other secondary	7.71	79	49	1462173	883664
11005436404	Other secondary	0.00	59	49	1462155	884327
11005437301	Other secondary	4.84	78	49	1461606	884863
11005471301	Other secondary	4.99	57	44	1407995	895119

11005498001	Diversion point	341.09	61	47	1468748	913112
11005505001	Diversion point	8.95	81	46	1439269	844150
11005505002	Diversion point	70.21	78	46	1439239	844182
11005505401	Other secondary	0.00	92	47	1438886	843512
11005505402	Other secondary	0.00	92	47	1439042	843257
11005507001	Diversion point	200.72	74	48	1465260	853589
11005514001	Diversion point	2.67	85	43	1402781	874202
11005514002	Diversion point	3.38	85	43	1403205	873859
11005514003	Diversion point	3.41	85	43	1403532	873526
11005514401	Other secondary	0.00	85	44	1403324	873105
11005522001	Diversion point	1.49	85	51	1471729	848658
11005560001	Diversion point	201.04	74	48	1465613	853143
11005565001	Diversion point	50.95	74	46	1437482	862772
11005565401	Other secondary	0.00	70	47	1437113	862732
11005572301	Other secondary	0.10	55	44	1405358	894201
11005576301	Other secondary	1.95	61	45	1418714	901183
61003927301	Other secondary	1.66	65	45	1424569	953542
61003928301	Other secondary	2.25	64	45	1424239	952698
61003929301	Other secondary	4.16	61	45	1422768	950609
61003930001	Diversion point	3.03	71	45	1427256	951969
61003930301	Other secondary	3.03	71	45	1427256	951969
61003930302	Other secondary	3.88	70	45	1426604	951393
61003930303	Other secondary	4.97	68	45	1426351	950874
61003931301	Other secondary	14.72	61	45	1427348	946617
61003932301	Other secondary	0.44	55	44	1414432	930611
61003933301	Other secondary	0.97	58	44	1415113	930527
61003934301	Other secondary	0.30	62	44	1412790	928266
61003935301	Other secondary	0.45	71	47	1429704	926374
61003936301	Other secondary	0.08	79	45	1417307	921465
61003936302	Other secondary	0.40	71	45	1417350	921625
61003937301	Other secondary	0.82	57	45	1419198	919114
61003938301	Other secondary	1.05	58	45	1419156	919712
61003939301	Other secondary	1.12	65	45	1421450	918695
61003939302	Other secondary	0.35	68	45	1421561	918243
61003939303	Other secondary	0.09	76	45	1421948	917906
61003940301	Other secondary	1.86	61	45	1425558	916419
61003941001	Diversion point	6.06	63	43	1390368	923511
61003941301	Other secondary	6.06	63	43	1390368	923511
61003942301	Other secondary	0.14	87	44	1408659	917543
61003942302	Other secondary	0.02	89	44	1408630	917729

61003942303	Other secondary	0.07	81	44	1409119	917720
61003942304	Other secondary	0.02	78	44	1409197	917914
61003943301	Other secondary	0.03	62	44	1413353	913665
61003944301	Other secondary	0.63	74	45	1420197	915295
61003945301	Other secondary	1.80	58	45	1419884	912944
61003946301	Other secondary	1.29	62	45	1422580	914296
61003947301	Other secondary	3.03	59	45	1424265	912736
61003948301	Other secondary	4.51	61	47	1434383	921538
61003948302	Other secondary	0.16	55	47	1433918	922154
61003949301	Other secondary	0.48	73	47	1438104	905084
61003950301	Other secondary	0.85	67	47	1438472	914969
61003951301	Other secondary	0.42	77	47	1441591	905176
61003952001	Diversion point	0.12	86	43	1400274	888592
61003952301	Other secondary	0.12	86	43	1400274	888592
61003953301	Other secondary	0.64	56	43	1391859	905539
61003954301	Other secondary	0.14	74	44	1404507	898350
61003955301	Other secondary	5.69	60	44	1412378	894181
61003955302	Other secondary	0.93	55	44	1412451	894012
61003956101	Other secondary	0.33	82	44	1401908	906109
61003957301	Other secondary	0.35	83	44	1413157	899034
61003957302	Other secondary	0.06	84	44	1412816	899158
61003957303	Other secondary	0.45	81	44	1413280	899058
61003957304	Other secondary	0.36	83	44	1413199	899046
61003958301	Other secondary	75.04	61	44	1421347	894103
61003959001	Diversion point	29.76	61	46	1434205	896869
61003959301	Other secondary	29.76	61	46	1434205	896869
61003960001	Diversion point	0.52	85	46	1434935	894798
61003960301	Other secondary	0.52	85	46	1434935	894798
61003960302	Other secondary	0.03	84	46	1435122	895280
61003961001	Diversion point	34.70	63	46	1434869	892890
61003962301	Other secondary	5.84	85	42	1389463	884089
61003963001	Diversion point	69.94	80	42	1397549	867733
61003963401	Other secondary	0.00	70	42	1397704	867279
61003964001	Diversion point	3.89	85	43	1400431	875312
61003964301	Other secondary	3.89	85	43	1400432	875312
61003965101	Other secondary	131.07	80	43	1412409	873864
61003965201	Other secondary	108.04	80	42	1403892	872491
61003965401	Other secondary	0.00	85	44	1404645	873392
61003965402	Other secondary	0.00	92	44	1406086	873573
61003965403	Other secondary	0.00	92	45	1408663	874042

61003965404	Other secondary	0.00	73	44	1404400	871430
61003966001	Diversion point	2.04	85	44	1405714	874952
61003966301	Other secondary	2.04	85	44	1405711	874956
61003967001	Diversion point	135.01	80	43	1413742	873379
61003968001	Diversion point	7.82	78	45	1427148	877764
61003968401	Other secondary	0.00	90	46	1427436	877537
61003969301	Other secondary	0.26	62	45	1436138	956094
61003969302	Other secondary	0.42	67	45	1436033	955995
61003969303	Other secondary	0.04	56	45	1436141	955727
61003970001	Diversion point	358.94	61	47	1470128	904910
61003970002	Diversion point	358.92	61	47	1470103	905124
61003971301	Other secondary	0.36	59	47	1439336	934003
61003972301	Other secondary	1.11	63	46	1433503	933109
61003973301	Other secondary	0.24	75	47	1433928	931069
61003974001	Diversion point	0.49	56	47	1438428	929407
61003974301	Other secondary	0.49	56	47	1438428	929407
61003975301	Other secondary	0.29	75	47	1440100	926592
61003976301	Other secondary	2.58	55	47	1442697	924603
61003977301	Other secondary	11.12	56	47	1447041	922496
61003978301	Other secondary	12.51	56	47	1447048	921059
61003979001	Diversion point	194.11	58	50	1479264	897316
61003979301	Other secondary	194.11	58	50	1479264	897316
61003979401	Other secondary	0.00	92	50	1480586	897074
61003980001	Diversion point	2813.61	65	46	1468759	879903
61003980401	Other secondary	0.00	92	50	1473860	881578
61003980402	Other secondary	0.00	70	50	1473822	881199
61003981301	Other secondary	0.37	64	50	1469132	868023
61003982001	Diversion point	86.87	70	42	1410838	847520
61003983001	Diversion point	1.40	70	44	1404930	866400
61003983401	Other secondary	0.02	70	43	1404419	865930
61003984001	Diversion point	2.79	74	45	1412562	867771
61003984002	Diversion point	2.92	74	45	1412856	867711
61003984003	Diversion point	5.59	79	46	1414188	867523
61003985001	Diversion point	344.44	73	44	1441159	852633
61003985401	Other secondary	0.01	91	48	1441124	852363
61003986001	Diversion point	345.45	73	44	1441849	852581
61003987001	Diversion point	0.18	92	48	1453298	852525
61003987002	Diversion point	468.62	76	45	1453003	852763
61003988001	Diversion point	713.67	78	46	1460965	849843
61003988501	Return flow	15.96	89	50	1461121	849708

61003989001	Diversion point	768.64	79	46	1463875	851834
61003990001	Diversion point	768.76	79	46	1464200	852034
61003991001	Diversion point	771.79	79	46	1465963	852420
61003992001	Diversion point	975.63	78	46	1466390	852389
61003992501	Return flow	7.66	81	50	1466528	851901
61003992502	Return flow	975.63	78	46	1466490	852323
61003992503	Return flow	7.57	81	50	1466490	851476
61003993001	Diversion point	985.83	78	46	1469853	851205
61003993501	Return flow	985.83	78	46	1469852	851205
61003994001	Diversion point	988.33	78	46	1471700	851904
61003994501	Other secondary	992.69	78	46	1472090	851929
61003994502	Other secondary	4.04	85	51	1471642	850942
61003994503	Other secondary	3.89	84	51	1471656	850669
61003994504	Other secondary	3.86	84	51	1471652	850497
61003995001	Diversion point	16.56	64	50	1465954	864347
61003995002	Diversion point	16.56	64	50	1465954	864347
61003995301	Other secondary	16.56	64	50	1465954	864347
61003996001	Diversion point	3959.26	68	46	1477400	851759
61003996501	Return flow	3959.42	68	46	1477640	851577
61004963001	Diversion point	450.02	65	45	1425454	918554
61004963301	Other secondary	450.02	65	45	1425455	918553
61004964001	Diversion point	2837.06	65	46	1468957	871753
61004964401	Other secondary	0.00	92	51	1479744	862136
61004965001	Diversion point	2837.06	65	46	1468958	871753
61004965301	Other secondary	2837.06	65	46	1468957	871753
61004966001	Diversion point	0.18	78	46	1425920	921884
61004966002	Diversion point	3.72	76	46	1427184	927247
61004966301	Other secondary	3.72	76	46	1427184	927247

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